BUILDER'S WORK

AND

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BY

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PREFACE.

I HAVE been induced to place this volume before such of the public as may be interested in Builder's Work and the Building Trades by the numerous applications that have from time to time been made for copies of my *Notes on the Building Trades and Building Construction,* which were first published in 1873, and a second edition in 1877, for private circulation amongst my brother officers and the N.C.O.'s of the Corps of Royal Engineers passing through the "Course of Construction and Estimating" at the School of Military Engineering, Chatham.

Those "Notes" were the embodiment of a set of lectures which, in the course of my duty, I had to draw up with the view of explaining the different kinds of work connected with the building trades comprised in the War Department Triennial Schedules of Contract; they have now been carefully revised and added to, and it is hoped may, in their new form, be of use to Engineering and Architectural students, as well as to many of the younger members of those professions.

The question of materials is only dealt with in so far as it practically bears on the proper execution of the work connected with each trade; so also with regard to details of construction, which are treated rather from the point of

view of those who may be actually engaged in the execution, or in superintending the execution of builder's work, than from that of the designers of such works.

The general subject of materials, as also of construction, both theoretical and as applied to ordinary engineering and architectural works, are dealt with in the other text-books used on the "Course of Construction and Estimating."

The Appendices on the Strength of Concrete and Timber, though not, strictly speaking, within the compass of this work, are given because they contain, in a useful form, the results of many careful experiments on subjects which have not yet been put upon a satisfactory basis.

H. C. SEDDON.

REVISED EDITION, 1897.

IN issuing this Third Edition a few additions, alterations, and necessary corrections have been made.

The principal additions consist of :—

Appendix II.—Fireproof Concrete.

Appendix III.—Specification for Mortars.

Appendix IV.—Specification for Portland Cement.

Appendix V.—Altered to—Specification for Concrete in Foundations, Floors, and Roofs.

Appendix VII.—Ordinary Stock Sizes of Planks, Deals, and Battens, and the Scantlings into which they are most readily converted.

H. C. SEDDON.

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Chapter III.

BUILDERS' WORK AND THE BUILDING TRADES.

OBSERVATIONS.

THE system adopted in the following pages will be to take the Building Trades separately, in the order they occur in the War Department Triennial Contracts, at the same time drawing attention to the different Schedules, the nature and arrangement of the items, the methods of arriving at the amount and cost of labour and materials, and any other points requiring special explanation. Attention will be directed to the various sources from which fuller information on such subjects may be obtained, and then nothing but the constant exercise of an intelligent observation, whenever opportunities offer, will be able to supply that practical experience which should always be brought to bear upon theoretical knowledge.

A knowledge of the nature and property of materials, and how to make use of them to the best advantage, is not of itself sufficient to ensure success as an Engineer or Architect. He must render himself familiar with all the customs and practices peculiar to the different Building Trades, and be capable of clearly explaining, as well as superintending, every detail connected with the work on which he is engaged before he can safely be called upon to work out a design himself, or even carry into execution the designs of others; in addition to which he must thoroughly understand every process finished work had gone through, in order to be in a position to value accurately the materials and labour consumed, or to judge whether there is a fair amount of work done in return for the time expended upon it.

Without such knowledge it would be impossible to estimate the cost of a proposed design with any degree of certainty, since

it necessitates measuring up in detail, taking out the total quantities, and ascertaining the correct value of every description of work involved. Nor would it be possible to draw out a *specification*—a set of explanatory instructions, in strict accordance with which a Contractor is bound to carry out his contract—in which every detail, not fully explained by the drawings, ought to be described with such clearness and accuracy as to admit of no possibility of disputes arising with the Contractor, either during or after the execution of the work.

The different Building Trades, as usually recognised, and for which separate Schedules are drawn up in the War Department Triennial Contracts, are as follows :—

BRICKLAYER'S WORK.
MASON'S WORK.
PAVIOR'S WORK.
CARPENTER'S WORK, INCLUDING IRONMONGERY.
SMITH'S AND IRONFOUNDER'S WORK.
SLATER'S WORK.
PLASTERER'S WORK.
PLUMBER'S WORK.
PAINTER'S, GLAZIER'S, AND PAPER-HANGER'S WORK.
GASFITTER'S WORK.

VALUATION OF WORK.

In estimating the value of work not included in the War Department Schedules, as well as for other purposes, such books as Laxton's *Builders' Price Book*, Atchley's *Builders' Price Book*, and Kelly's *Practical Builders' Price Book*, are of the greatest value.

In them will be found the London prices for all kinds of work, labour, and materials connected with the building trades, together with full information with regard to the ordinary methods of measuring up and valuing the same.

The mode of measuring work in the different trades is given, in a more abstract form, in Hurst's *Architectural Surveyor's Handbook*; and in a more complete form in such works as Fletcher's *Text Book, Quantities*; Leaming's *Quantity Surveying*; Dobson's *Student's Guide to Measuring, etc.*, new edition by E. W. Tarn.

In order accurately to fix the value of any work from a London *price book*, it is necessary to take into account the difference between the rate of wages quoted in the book—upon which the cost of the different kinds of work is based—and those current at the particular time and place in question, as well as any difference in the price of the materials delivered on the spot.

A number of practical problems in valuing work of different descriptions are given, fully worked out, in a chapter on the "Principles of Estimation" in Tate's *Principles of Geometry, Mensuration, etc.*

Constants of labour, embracing all descriptions of work connected with the building trades, are given in Hurst's *Handbook,* as also in Rankine's *Useful Rules and Tables.*

They are of special value in setting out *task* and *piece-work,* as well as in calculating the amount and cost of the labour involved in the execution of builders' work of every description.

The constants of labour affixed to the different items, in the books quoted above, represent the time—in terms of 10-hour days—it ought to take a man to do a unit of each particular kind of work. These constants, multiplied by the rate of wages paid to the workman, will give the cost of the labour involved in executing a unit, and hence any amount of each kind of work.

In applying them, it must be remembered that they are calculated for the average London workman; moreover, that large quantities of work, in which the same operations are many times repeated, can generally be done in a shorter time than small jobs.

Sometimes constants of labour are employed in which the time is constant, and the amount of work done varies according to its nature, instead of the time varying according to the nature of the unit of work in question.

If it be required to arrive at the full value of the work, there must be added to the cost of the labour the expenditure, if any, on materials consumed, and a percentage to cover wear and tear of tools—when not provided by the workman—as well as superintendence and plant, including rent and maintenance of premises.

CHAPTER I.

BRICKLAYER'S WORK.

EXCAVATOR'S WORK, though comprised under the head of Bricklayer's Work, must, for the sake of clearness, be described separately.

EXCAVATOR.

In large engineering operations, such as forming Docks, Railway Cuttings, Embankments, etc., excavating forms a distinct business, often requiring the possession of extensive and costly plant; but the excavator's work connected with ordinary building operations, being for the most part a much simpler matter, is treated as a branch of the bricklayer's trade, as may be seen by turning to any Builder's price-book, or to the *Schedules of Contracts for Works and Repairs to War Department Buildings,* where, under the head of "Bricklayer," are included, amongst other things, excavating, carting, wheeling and basketing, filling-in and ramming, soiling embankments and forming slopes, making puddle walls, well sinking and boring, laying concrete and gravel, etc.

Excavating.

The actual work of digging out the ground for the foundations of a building requires no special description.

Tools.—The principal tools employed are different kinds of *picks* for loosening hard ground—*crowbars* for breaking up and removing obstacles—*spades* and *shovels* for digging and throwing out the soil; including special spades, such as *grafting tools,* the blades of which are formed like a scoop, for digging clay; and *spades* with wedge-shaped blades for cutting deep, wedge-shaped trenches for drain pipes—besides *squares, levels, boning rods,* 10-feet *rods,* and *lines* and *pegs* for setting out work on the ground.

Valuation.—Excavating is paid for by the cubic yard, the cost depending on the stiffness of the soil and the depth of the

sinking. The prices, which vary with the nature of the ground, increase with each additional depth, or *throw*, of 6 feet, as shovellers are required at each 6-foot level to pass the stuff up to the surface.

A higher rate is paid for depths beyond 6 feet in the case of excavations in confined spaces, such as tanks, cesspools, and trenches under 2 feet 6 inches wide, on account of the extra trouble in getting out the stuff.

There are special items in the War Department Schedules which include providing and fixing shoring in the price of the digging and throwing out; otherwise it is often valued by the foot super, or by the yard run, for use and wear and tear, according to the nature and extent of the timbering required; about one-third of the value of the stuff used, added to the cost of the labour on it, is an ordinary way of fixing the price. The best plan is to charge for the timber used, and to take it back at a fair valuation, after the completion of the work.

In all cases the prices allowed for excavating include keeping the excavations clear of all water arising from rain or ordinary soakage; but should extraordinary appliances be required, such as pumping, cofferdams, pile driving, etc., special prices must be paid, as the digging becomes the least expensive part of the work, and superior labourers are required, accustomed to the use of pile engines, etc., and capable of performing all the rough carpentry connected with the timbering of large excavations.

As an assistance in fixing or judging the fairness of prices, as well as in setting out task-work, it may be considered that a good excavator will dig and throw out into a barrow, in a day of 10 hours—

	Cubic yards.
In common ground, from . . .	8 to 10
In stiff clay or firm gravel, about . .	6
In hard ground, where picking is required, from	3 „ 5

Contents of Earthwork.—In estimating the number of cubic yards, the solid content, before breaking up, is taken; if therefore the measurements have to be got at from a loose heap, a deduction must be made according to the nature of the soil. In ordinary soils, the usual practice is to deduct one-third or one-fourth.

Experiments have given the increase in different soils as follows (Hurst's *Handbook*):—

(1)	Earth and clay, before subsidence . .	About $\frac{1}{4}$
(2)	Sand and gravel, or clay and earth, after subsidence	„ $\frac{1}{12}$
(3)	Chalk } depending on the size of the pieces . .	„ $\frac{1}{3}$
(4)	Rock } depending on the size of the pieces . .	„ $\frac{1}{2}$

In accordance with the above data, the respective deductions to be made from a loose heap, in order to get at its content before breaking up, would be (1) $\frac{1}{5}$; (2) $\frac{1}{13}$; (3) $\frac{1}{4}$; (4) $\frac{1}{3}$; but the increase of bulk in any particular soil, when dug and thrown into a loose heap, if great accuracy is required, should be ascertained by actual trial.

On the other hand, if the earth dug out has to be measured after having been made up into an embankment, a similar correction must be made to arrive at the content before breaking up, as most soils compress into less space than when lying in a natural state of deposition. The proportion to be added may be estimated from the following data (Garbett's *Student's Guide*):—

Light sandy earth occupies about the same space in embankment as before digging.
Clayey earth about $\frac{1}{10}$ less.
Gravelly earth $\frac{1}{12}$ less.
Rock in large fragments about $\frac{5}{12}$ more.
Rock in small fragments about $\frac{3}{5}$ more.

This difference of bulk must therefore be considered in estimating the amount of stuff required to form any given embankment; as also in fixing the height to which embankments, as for railways, are to be laid out, in order to allow for settlement. The ordinary allowance is 1 inch to 1 foot, though in some cases as much as 3 inches is necessary.

In trenches for footings of walls, a space of 6 inches is generally allowed on each side of the lowest footings for working room, or more in loose soil; and in trenches for drain pipes, the width at bottom is taken at 1 foot in addition to the diameter of the pipes employed; but in excavations for sunk stories, or concrete, the net widths only are allowed.

Deep and narrow trenches are usually made at least 3 feet wide, and 4 feet wide if over 9 feet deep.

For methods of getting out the cubic contents of irregular pieces of earthwork in banks or excavations, see Rankine's *C. Eg.*, or his *Rules and Tables*, also *R. E. Aide Mémoire*, pars. 866-874.

Shoring and Planking.—In loose soil the sides of shallow excavations may be sloped off; but, if they are of any depth, shoring, or strutting and planking, would be cheaper. Such precautions are often absolutely necessary to prevent accidents arising from the falling in of the sides; for, though different soils will retain a vertical face for a short time in favourable weather, excavators often expose themselves to unnecessary risks, a practice which should never be permitted.

The height of this temporary vertical face varies with the cohesive properties, as compared with the weights of different earths, and may in practice be taken as follows (Hurst's *Handbook*) :—

	ft.		ft.
Clean dry sand and gravel from . .	0	to	1
Moist sand and ordinary surface mould .	1	„	3
Loamy sand, well drained . . .	5	„	10
Ordinary clay	9	„	12

These heights differ somewhat from those given in Rankine's *C. Eg.*, p. 315, but the difference is on the safe side.

When the ground is firm enough to admit of it, deep and narrow trenches, say under 6 feet wide, may be secured by hori-

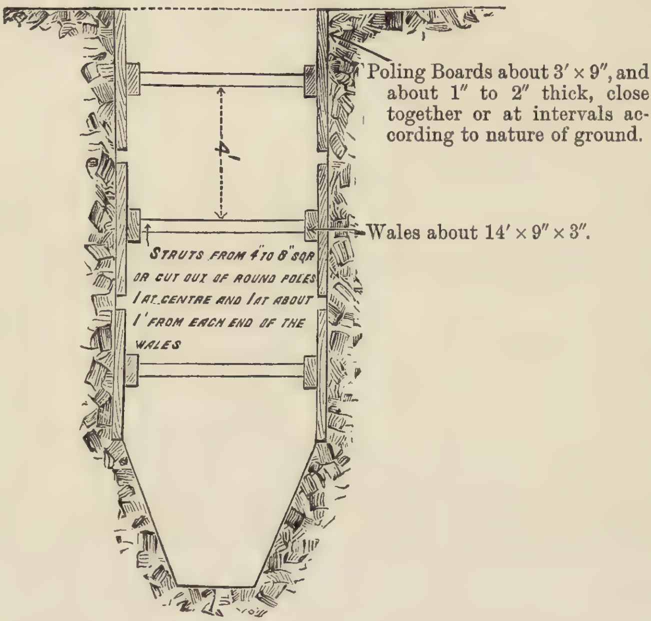


Fig. 1.

zontal planks or *wales*, placed opposite each other—the first at about 2 feet below the surface—and kept apart by struts 4 inches square and upwards, or round sticks 5 or 6 inches in diameter, cut about 1 inch longer than the horizontal distance between the planks; they are placed aslant between the planks, and driven till square across the trench, when they will generally be found sufficiently tight to carry a staging upon them, if required. A good size for the planks is 14 feet × 11 × 3 inches, which allows

of three struts, about 6 feet apart, one at the centre, and one at about 1 foot from each end. If the planks and struts are then placed at vertical distances of 3 or 6 feet, horizontal stages can be formed at 6 feet vertical intervals by placing planks lying across

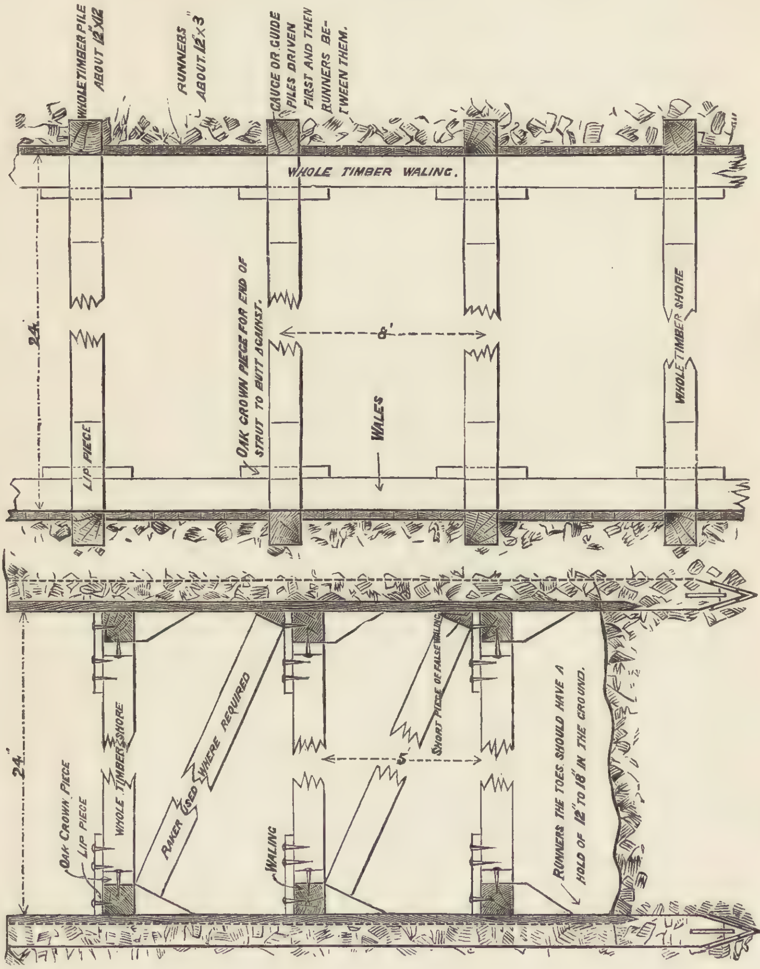


Fig. 3, Plan.

Fig. 2, Section.

two or three of the struts, according to the length of stage required; by this means the stuff can be thrown from stage to stage, the vertical throw being, for ordinary earths, taken at 6 feet from level to level, as explained further on. Of course the stages must be conveniently arranged, not directly over each other. From the top stage the earth must be thrown and heaped,

so as to leave at least 2 feet clear along the side of the trench, for getting along.

Fig. 1 shows the method of shoring ordinary trench work, when the ground requires short vertical or *poling* boards behind the wales at vertical intervals; whilst Figs. 2, 3, and 4 show the timbering actually used in getting out foundations in very bad ground when constructing the Chatham Dockyard

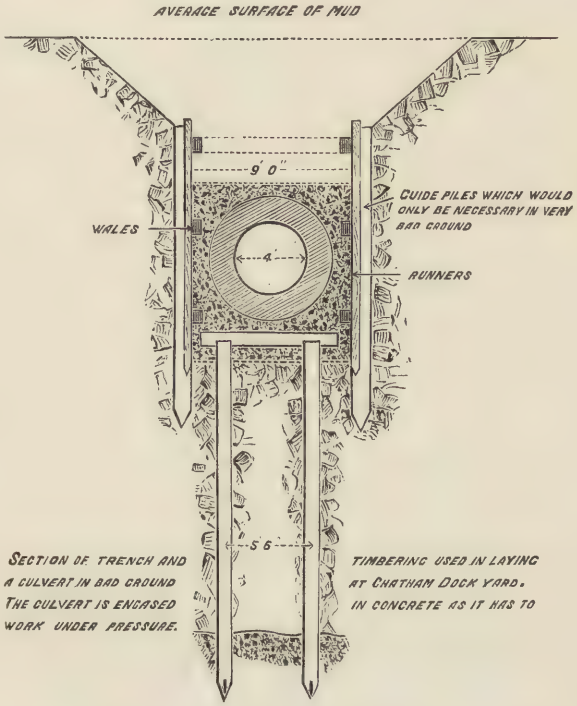


Fig. 4.

Extension Works, where, in some cases, even whole timbers (13 by 13 inches) were crushed and broken up, owing to the ground on opposite sides of the trench being unequally loaded, causing the timbering to sink on one side and rise on the other.

When running sand or very soft clay has to be kept out, straw or stable litter may in some cases be rammed in behind the *poling boards* in Fig. 1; and it may be necessary to caulk the joints between the vertical sheeting or *runners*, shown in Fig. 4.

For shoring cofferdams, houses, etc., see chapter on "Shoring

and Strutting" in Hurst's *Tredgold,* also *R. E. Aide Mémoire,* pars. 925, 926.

Large Excavations.—In extensive excavations it is necessary, in order to combine speed with economy, to carefully proportion the number of pickmen, shovellers, wheelers, etc., and to resort to many expedients for *getting* and removing the *spoil,* not necessary in ordinary building operations. For special information on this subject, see *R. E. Aide Mémoire,* pars. 866-880, and Rankine's *C. Eg.*, p. 336, "Labour of Earthwork."

Carting, Wheeling, etc.

The digger or *getter* (this term implies the use of the pick) is only supposed to remove the *spoil,* as the stuff got out is called, one throw, viz., from 6 to 10 feet; for any greater distance the cost of removing must be allowed in addition, either as *shovelling, carting, wheeling,* or *basketing.*

In excavating over large surfaces, the price per cubic yard usually covers nothing but the getting and removing the spoil one throw; so that, if necessary, the carts or barrows must be brought into the excavations, or near enough to avoid more than one throw from the heaps into them.

In narrow excavations and trench work, such as for foundations to walls, etc., the price charged generally includes removing the spoil to the surface of the ground, and depositing it at a safe distance from the edge of the bank; from which point the distance for carting, etc., should be measured.

Carting.—Carting is estimated at so much per single or double load,[1] by the *run* of one furlong (220 yards), including

[1] The load varies with different materials, thus—

A single load of sand, earth, rubbish, or a measure or hundred of lime . .	= 1 cubic yard.
,, ,, squared or hewn timber, deals, etc.	= 50 cubic feet.
,, ,, unhewn timber . .	= 40 cubic feet.
,, ,, bricks . . .	= 500 bricks.
,, ,, tiles	= 1000 tiles.
,, ,, water . . .	= 1 butt of 108 gallons.
,, ,, light, bulky materials .	= 80 cubic feet.

There are 1·283 cubic feet nearly in a bushel, and therefore a little over 21 striked bushels in a cubic yard. In the War Department Schedules a load or yard of lime, in lump, is taken to mean 22 bushels. A load of sand is in some localities 36 bushels, and a load of lime 27 or 32 bushels. A hundred of lime actually contains 100 pecks or 25 bushels, which would fill a 3 ft. 2 in. cube; it is, however, generally taken to mean a cubic yard heaped up. Cubic-yard measures are generally wooden boxes open at top and bottom, and made in two heights of 18 inches, for ease in handling.

filling the carts; an extra amount being charged for each additional *run* beyond the first.

In large excavations, *leading,* as it is termed, is performed in three-wheeled carts, called *dobbin* carts, which hold about $\frac{3}{4}$ cubic yard; or in *earth* or *tip* waggons, holding from $1\frac{1}{2}$ to 3 cubic yards, drawn on temporary rails by horses, contractors' locomotives, or wire ropes worked by stationary engines (*vide* Rankine's *C. Eg.*, p. 336, 5th ed.).

When such excavations are over 20 feet deep, the spoil may be raised by vertical or inclined lifts, worked as single or double horse runs; but for less depths they would not be economical. Or the same system may be worked as double, or even quadruple steam lifts. Also stationary or travelling steam-cranes may be used to work *skips,* which are large boxes of iron or wood, made to hold about 1 cubic yard of stuff, and so constructed that, when raised and held by the crane over a waggon, they can be made to discharge their contents either by turning over or opening out below. Woodford's patent iron skips, on the latter principle, are the best.

For sketches, details, and prices of crabs, cranes, travellers, skips, pumps, tip waggons, barrows, contractors' fixed and locomotive engines, etc., see Appleby's *Handbook of Machinery and Ironwork,* Bolling and Lowe's *Price Books,* etc.

Wheeling.—Wheeling is more economical than carting for distances under 100 yards. The barrows used hold about $\frac{1}{10}$ cubic yard, and are mostly run on planks, which are not generally laid with a greater inclination than $\frac{1}{12}$, unless aided by ropes and winding machinery.

Each foot of rise is usually considered equal to 6 feet on the level; but by the War Department Schedules wheeling is paid for by the cubic yard, at a given price, for a run not exceeding 50 yards horizontal and 3 feet rise. The price increases with each additional run of 25 yards, extra being allowed for a rise of over 3 feet and under 10 feet, with a further addition for every 5 feet in height over 10 feet. The price includes filling the barrows.

By a skilful disposition of the spoil in the barrow, especially if got out in lumps, as is the case with clay, the centre of gravity of the mass is thrown forward over the wheel when the barrow is lifted; consequently, the wheeler, by being relieved of a portion of the weight, can travel faster, and so do more work in the day.

For estimating the proper proportion of wheelers to fillers, shovellers and getters, see Rankine's *C. Eg.*, p. 337.

Barrow Runs.—The method of constructing and arranging barrow runs in extensive excavations, so as to keep all the hands fully employed and to prevent the crossing of barrows, which would necessitate the use of a wide road and inevitably lead to confusion and loss of time, requires careful consideration.

In making barrow runs on an incline, for wheeling the stuff out of excavations, supports called *box horses* (Fig. 5) are used, either singly or resting on edge, one on top of another, if greater height is required. They are mostly from $1\frac{1}{2}$ to 3 feet square,

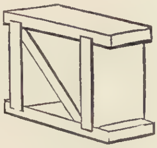


Fig. 5.

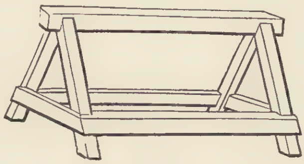


Fig. 6.

and made out of 11 by 3 inch planking. If a considerable height is required rough *trestles* are made use of, such as Fig. 6; but, wherever practicable, box horses are preferred, as stronger and less likely to get out of order than trestles, which require some skill in carpentering to construct and repair. Runs Nos. 1, 2, and 3 (Figs. *7a*, *7b*, and *7c*) are such as were used in constructing the Chatham Dockyard Extension Works.

Basketing.—Removing earth, etc., in baskets is only resorted to where a barrow cannot be worked, as in carrying earth up or down steps, etc. The cost is greater than that of wheeling, but is paid for in the same way, by the yard cube, at a price per *run* of 25 yards, and extra for each run beyond the first.

Filling in and Ramming.

This, in ordinary building operations, consists of filling in the earth round the footings of walls and in trenches for drains, etc., in regular layers of from 6 to 12 inches, and ramming or *punning* (probably a corruption for pounding) each layer with wooden rammers or *punners*. Sandy ground should be consolidated by watering, for punning dry sand or clean dry gravel is a waste of labour.

Fig. 7a.—RUN Nº I ON LEVEL.

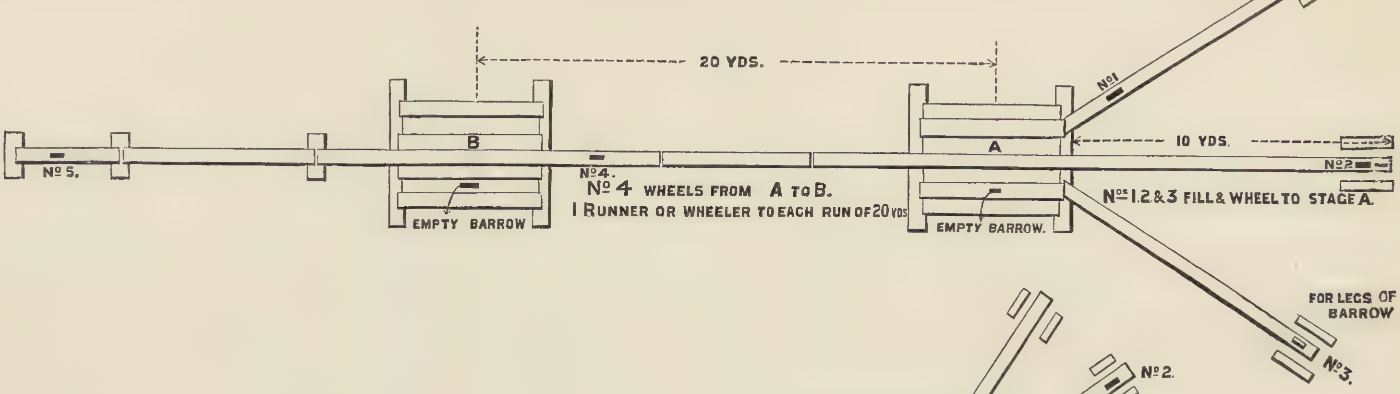
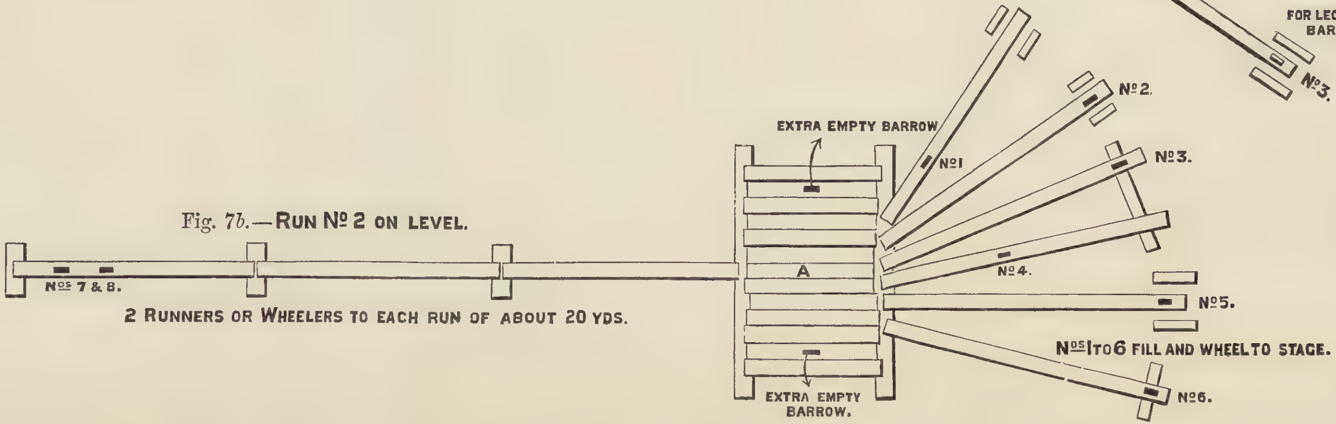


Fig. 7b.—RUN Nº 2 ON LEVEL.



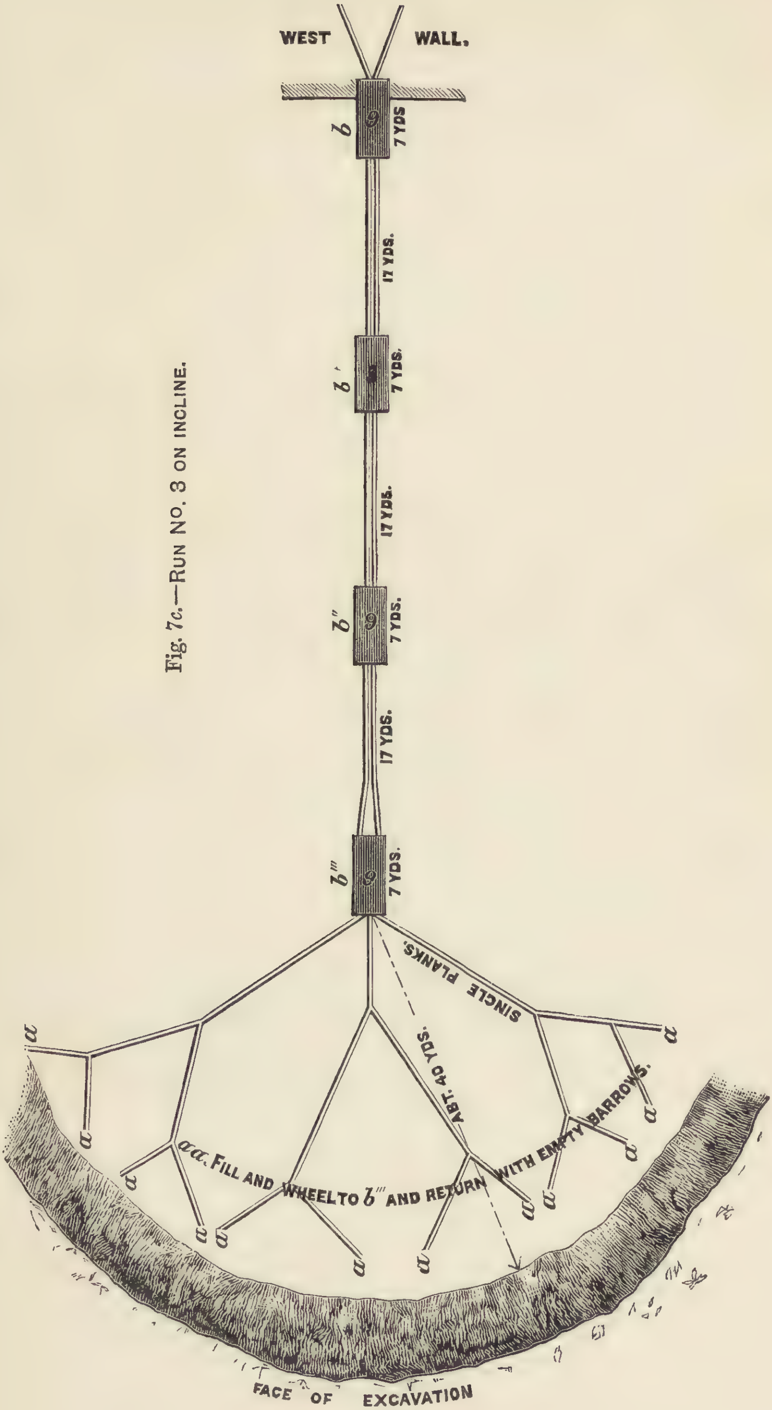


Fig. 7c.—Run No. 3 on Incline.

It is of the utmost importance to ram solidly beneath and round the sides of pipes, to prevent their sinking, from the ground yielding or being left hollow below them; the smaller stuff should be selected for this purpose. The practice of allowing for settlement by filling in trenches for pipes, etc., to a much greater height than the level of the ground, is dangerous where wheeled traffic has to pass. It is better to let the earth sink a little, and then fill up the hollow as may be required.

One man cannot ram properly more than one filler can shovel to him; but as, in trench work, at least 2 feet should be left between the edge of the trench and the foot of the heap thrown out, which may occupy a great width of base, it may require two fillers to supply one rammer. For instance, the stuff thrown out by the side of a trench 3 by 10 feet deep will leave a width of base of about 9 or 10 feet, which would necessitate two throws from the far side of the heap, one to the filler and one by him.

One man can fill in about 20 yards a day, consequently at least one filler and one rammer are required for each 20 yards per diem required to be filled and rammed.

It is a common practice in trench work for footings to walls, instead of going to the trouble of taking out the contents, to take a fair proportion of the digging and throwing out for filling in and ramming, depending on the proportion the sectional area of the foundations bears to the sectional area of the trench in which they stand.

Filling in and ramming is paid for by the cubic yard.

Soiling Embankments and Dressing Slopes.

This work is paid for by the yard super, and is sufficiently explained in the wording of the items of the War Department Schedule referring to it.

The whole subject of cuttings and embankments is reviewed in Rankine's *C. Eg.*, p. 344.

Clay Puddle.

Puddle is used to make reservoirs, embankments, and cofferdams water-tight, as well as to protect the backs of walls and arches from the penetration of water.

It is formed by working clay about, in layers about 9 inches thick,

with sufficient water to make it pasty, by means of a special tool, with a kneading action, or by cutting and cross-cutting it with a spade, until it becomes a perfectly homogeneous and compact mass. When required in large quantities it may be well worked up in a pug-mill freely supplied with water, then transported where required, which further consolidates it, and finally rammed or trodden down *in situ.*

It should be free from large stones, roots, or any vegetable matter likely to decay. Some engineers consider that a certain amount of sand or fine gravel, by enabling it to hold water better, renders it less liable to crack in dry weather; but if the puddle is thoroughly worked up with sufficient water there could be no tendency to crack, except at the surface, where, perhaps, this course might be pursued, as well as at the ends of a puddle wall, where any drying and consequent shrinking would afford a passage for water.

Gravel is also sometimes used to give puddle a greater stiffness, especially where it has to carry a superincumbent load.

To guard against its being bored through by vermin a bed of loose sand has been placed next to it, with the idea of the sand falling in upon any attempt to burrow through it; but as the sand, if not perfectly clean and dry, would cling together, such a system should not be relied on. Coarse gravel and stones have also been used, as well as flags and slates, to wall the sides of the puddle, and to prevent its being damaged by vermin.

Clay puddle, when used in layers of about 6 inches thick, as over arches, is valued at the yard super; but in thick masses by the yard cube.

Well Digging.

Under this head, in addition to the excavating, is included *steining,* or lining the well with brickwork, stone being rarely used. This, except in chalk or rock, is necessary to prevent the sides of the well from falling in, and even then it is required at the top for safety, on account of the looseness of the surface soil, and in some cases to keep out land springs.

Wells are made circular in form, the only special apparatus usually required being a *plumb-bob* and a *gauge-rod,* equal in length to the diameter of the well, to insure accuracy in sinking, with buckets, windlass, and ropes for removing the spoil.

Steining.—The *sinking* (in the War Department Schedules)

is paid for by the yard cube, at a price increasing with every 10 feet in depth after the first 20 feet, and including keeping out water and removing the spoil within 50 yards.

The *steining* is paid for separately by the foot cube.

The method ordinarily practised in London is to charge for well-sinking by the foot in depth, according to the description of the ground, the diameter in the clear of the brickwork, the depth of the sinking, and the nature of the steining.

On the subject of well-digging, see *Well-Digging and Boring* (Virtue and Co.'s Series), where specifications and tenders for the execution of wells and borings are also given.

The thickness of the steining depends on the firmness of the soil and the diameter and depth of the well, ranging from $4\frac{1}{2}$ inches, for depths not over 6 feet, up to 14 inches, but rarely over 9 inches or one brick. The bricks must be laid so as to break joint, and should be in concentric $4\frac{1}{2}$-inch rings, if the steining is more than a half brick thick. The bricks employed should be hard, square, uniform in size and shape, and well burnt; a soft crumbling brick being useless. Malm paviors are very good for the purpose. If stocks are used they must be very carefully picked.

The old method of putting in the steining was by building the brickwork on a wooden ring or *curb*, shod with iron, in the same way as well foundations, as they are termed, are to this day sunk in India. The curb, weighted by the superstructure, sinks as the earth is removed from the inside until it will sink no farther, when a smaller curb is sunk in the same way within the larger one, and so on, until the requisite depth is obtained. This method is still used in sinking in loose ground.

The present method is to commence the steining at the top, continually under-pinning or adding to it below, as the excavation deepens. When the friction and swelling of the ground, from exposure to the air, is insufficient to prevent the steining from slipping down, artificial means have to be employed, such as the use of wooden or iron curbs, either temporary or built in, suspended by iron rods to beams laid across the top of the well or strutted up from below.

The following is an extract from Adcock's *Engineers' Pocket-book* for 1869 :—

"Of the construction of the common well there are two modes in use, adapted to dry or firm and wet or loose ground respectively. Where the ground is of the former character the excavation is

carried down to a safe depth, and made level around at bottom; upon this is laid a curb or ring of timber, formed in two or more thicknesses and lap-jointed, to equalise its strength, cut circular on the inside, but not on the outside, of a breadth sufficient to receive the brick lining of the well, and not less than 3 inches thick. On this, truly concentric with a central plumb-line, the brick lining is built up to the surface—the earth, or puddling of clay, being punned hard in around the outside as the work rises. The excavation is now resumed in the centre, leaving enough earth undisturbed under the curb to support the work done. When a safe depth is again attained the earth under the curb also is removed in four equidistant places, the duty of support devolving temporarily on the intermediate portions left as piers; and from a broad central footing of timber four raking struts are set up, and firmly fixed, to support the curb in the points from under which the earth was taken; this being done, the piers of earth are dug away, and the bottom is then, as before, made level around, as a bed for a second curb; and thus the work proceeds in stages down to the required depth, the projecting angles of the curbs outside, by their penetrating the soil, contributing to the support of the brickwork in its progressive extension downwards. When the ground is known to be of the wet or loose description the old method is to render the surface of the ground in the site of the well perfectly level, and to lay thereon a curb composed of ribs, clad outside with boarding, and forming a cylinder, say 6 feet long, with a smooth exterior and sharp lower edge, so that when the ground underneath and within it is excavated in a regular manner, and brickwork is built upon it to form the lining of the well, it sinks by its own gravity—the sinking below and the addition above keeping pace with each other, and the bricklayer continuing outside at the surface while the digger inside descends—the soil being hoisted out as fast as the latter excavates it, and the process continuing until the desired depth is attained. From the swelling of the ground the descending work usually by and by becomes bound, and then the process has to be recommenced at its base to a smaller diameter."

The principal part of the steining consists of *dry steining,* or laying the bricks without any mortar; but rings of bricks in cement should be built in at intervals, to strengthen the rest of the work. In the London clay these rings are placed at vertical intervals of from 5 to 12 feet, averaging about three courses in

height, and may, in under-pinning, be often used as a base to start each length from, instead of a wooden curb.

It is often necessary to lay the upper part of the steining in cement, in order to keep out surface drainage.

Good steining should be truly vertical. Any want of regularity can be detected at once by looking up from the bottom of the well, the eye being placed close to the steining.

Loose wet sand, or loam, requires great skill in sinking through, and may necessitate the use of puddle, or, which is more effectual, of hydraulic concrete behind the steining, care being taken to prevent the brickwork from slipping during the process of filling in behind.

Iron Cylinders.—Land and Sand Springs may often be walled out by executing a portion of the steining in cement, but should the rush of water be great, as in sinking through the mainland springs of the plastic clay formations, the water may have to be dammed out by using cast or wrought-iron cylinders, which sink as the excavating goes on inside them. During this process the water must be kept out of the cylinder, either by pumping or by forcing in compressed air on the principle of the diving bell. It often happens, however, when sinking in sand, that the pressure of water is sufficient to blow up the sand at the bottom within the cylinder; in which case the sand may be removed, without getting rid of the water, either by pumping or by means of a large auger, called a *miser* or *mud-shell.*

Wrought-iron cylinders are made of plates riveted to internal ribs, and flush on the outside, the rivets being countersunk, so as to present the least resistance possible to sinking.

Cast-iron cylinders, from their greater weight, sink more easily, and are usually cast in about 5 feet lengths, and joined together by internal flanges and bolts.

In order to secure the vertical sinking of the cylinders, four timber guides are usually fixed to the brickwork, which generally requires to be supported from above. The space between the top of the cylinder and the lower part of the brickwork should be filled in with hydraulic concrete, to keep the water from forcing its way into the working.

Boring.

Cost of Boring.—The cost of boring depends on the nature of the ground, the diameter and depth of the boring, and whether or

not pipes have to be used to prevent the soil choking the passage of the tool. It is paid for by the foot run, and is resorted to in making trial borings for wells, as well as in ascertaining the nature of the underlying strata before laying in foundations. *Vide* Rankine's *C. Eg.*, p. 331-333.

Boring Tools.—Boring tools may be classed as follows:—

1*st.* Tools for cutting through the ground by means of a *rotary motion,* such as *augers* and *worms.*

Augers are used for cutting through, and bringing up, ordinary earths, shales, and soft rocks, or for bringing up the disintegrated stuff at the bottom of borings. They are made on the same principle as the wood auger, the body being a hollow cylinder, terminated by a point or cutting edge, and a species of tongue to support the loosened materials; for running sand they are conical, or closed with clacks, to prevent the loose stuff from falling back into the bore, and are called *misers* or *mud-shells.*

For boring through thick beds of hard rock special rotary tools, such as the *diamond drill,* are now used.

Worms are sharp-pointed spirals used for boring rock too hard for the auger.

Augers and worms of increasing diameters are used to enlarge holes already bored.

2*d.* Tools for breaking their way through hard rocks by *percussion,* called *jumpers,* with cutting or pointed ends like chisels. They are worked by being raised, slightly turned, and allowed to fall again, disintegrating the rock by the momentum due to their weight alone.

3*d.* Tools such as *screw-taps, clutches, hooks* and *screws,* used for removing broken rods, etc., from the bore holes.

Boring tools are made of wrought-iron, steeled at their cutting edges, and fitted at the top with a screw joint, for the purpose of adding the lengthening rods as required.—See *Well Digging and Boring* (Virtue and Co.'s Series), also *Instructions in Military Engineering,* vol. i.

Ballast.

This is a term derived from the frequent use of similar materials for the purpose of giving stability of flotation to ships. It is used in the shape of broken stone, gravel, etc., as aggregate in making concrete, as a coating for macadamised roads, and on rail-

roads, to afford a firm and dry foundation for the sleepers which carry the rails, and is charged for by the load or yard cube.

The sources from which ballast can be obtained should be carefully noted in exploring the course of any projected road or railroad.

Ballast for Roads and Concrete.—For metalling a macadamised road, stone ballast should be broken so as to pass through a $2\frac{1}{2}$-inch ring in every direction. For concrete, its size depends entirely on the thickness or mass of the work, see p. 24.

Ballast for Railroads.—On railroads the ballast is laid in two beds; the *under ballast,* from 9 to 18 inches deep, carrying the sleepers; and the *upper ballast* or *boxing,* from 6 to 9 inches deep, packed round the sleepers, chairs, and rails, up to within 2 or 3 inches of the top of the rails.

The best description of ballast is broken stone. For railroads it may be of a softer nature than for common roads, but not such as is liable to rapid decay from the action of the air and moisture. Slag from ironworks, the refuse of alum-works (which is burnt shale), gravel, or even engine ashes may be used; but sand is objectionable, from its liability to be washed away in wet weather, and blown about in dry weather, when it damages the rolling stock by clogging the working parts.

Burnt Clay Ballast.—*Burnt clay ballast,* in the absence of ready-made ballast, is made from any clay suitable for brick-making, so that the spoil from clay cuttings may often be most economically utilised in this way. If thoroughly burnt, it will make an excellent lasting material for railroads, foundations of common roads, or concrete; and, when ground, for making mortar, either in addition to or in place of sand. The following is a description of the process of burning ballast, as given in Adcock's *Engineer's Pocket-book* for 1869:—

"The stiffer the clay is the better it is for burning, and the better is the ballast formed with it. Stiff clay will take 2 cwt. of coal to the cube yard, but open loamy stuff may take as much as double that quantity. When stiff clay is obtained, and is found covered with loamy soil, the latter is thrown aside as unsuitable.

"The best coal for the purpose is rich bituminous 'slack'—the richer and the smaller the better, provided it is not 'dust,' of which it should contain as small a proportion as possible. Of the rich bituminous kind, one half the quantity will suffice that

is necessary of the hard, dull, slaty qualities, such as the Silkstone, which commonly contains much rubbish.

"The coal trucks generally contain an admixture of three or four kinds of coal, but by a little inspection an experienced hand will be able to judge whether they contain a fair proportion of the good coal.

"The best time of the year for clay-ballast burning is, say, from the latter end of August till the latter end of December, the weather then being comparatively dull. The sun shining upon the burning heaps has the same detrimental effect upon them as upon an ordinary indoor fire.

"In rainy weather the consumption of fuel is increased, much more being expended in mere drying; in such weather, also, the fires require the use of the bar or poker more than in dry, to prevent the material from clinkering.

"A *grafting tool* is the best spade for digging clay generally. It has a crutch handle, and the blade is cylindrical, about 12 or 14 inches long, and half as wide.

Common shovels are wanted for the firing and heaping; also drags and bars, as well as barrows, planks, box horses, and trestles, for forming one, or perhaps two, feeding runs, leading on to the top of the heap.

"The *drag*, or iron rake, has about three teeth, 7 or 8 inches long, and $4\frac{1}{2}$ or 5 inches apart. The handle, which is wooden, is 10 or 12 feet long. Three of these are wanted for a large heap—two at top and one at bottom.

"The *bars* are long iron prickers or pokers, pointed at the end, and of several strengths, say from $\frac{3}{4}$ to $1\frac{1}{4}$ inch diameter. Three are wanted to each heap; two from 10 to 12 feet long for the top, and one about 5 feet long for the bottom.

"The men employed upon a large heap may generally be estimated as follows:—

At the bottom—

4 *fillers*, filling the barrows.
2 *runners*, delivering the clay.
4 *spreaders*, laying on the clay.

The latter have also sufficient time, while the top men are finishing, to lay on slack,—extending, say half-way up the heap.

At the top—

3 or 4 (generally 4) fillers, supplying runners.

2 runners, on the road, taking up clay only; the one going from the lowest stage or horsing to a half-way stage, the other from the half-way stage to the top.

1 runner, wheeling up coal, which he takes from the heap, and delivers on the top.

2 spreaders, on the top, receiving and laying on the clay.

1 spreader, laying the coal,—extending, say half-way down the heap.

Say 20 in all.

"The heap is formed as follows:—A cone, about 10 feet in diameter and 6 feet high, is formed with—1*st*, a wisp of straw or shavings; 2*d*, small faggot-wood; 3*d*, stout arms of trees, cut from 3 to 5 feet long and about 3 inches thick; and 4*th*, large coal (of which sufficient may generally, though not always, be picked out from the slack), leaving through these layers, at bottom, from centre to outside, a touch-hole, filled with straw or shavings, to fire by. When the cone is completed, it is set alight, and the clay and slack are added, in alternate layers, but not until the fire is bursting through the large coal. The grafting tool will turn out slices of clay about a foot thick; but these are too large for the earlier layers, and must be broken into little pieces. The first layer of clay is about 4 inches thick; over this is laid just enough slack to blacken it all over; then is put on a layer of clay, say 6 inches thick; and upon it a layer of slack a little thicker than the preceding. In this manner, layer upon layer, clay and coal are put on—the farther out, the larger the clay and the thicker the coal, but the latter never exceeding half-an-inch. In the first instance, the fire bursts out all over, excepting perhaps the lower foot and a half all round; the unburnt, and imperfectly burnt part, is therefore shovelled out, the upper part raked down with the drag, and a fresh layer of slack thrown over the face of the fire, and covered over with clay, mixed with the part just shovelled off. The operation is now carried on,—barring or poking up, dragging it uniform and smooth, and putting on fresh layers, alternately, of coal and clay—usually about two coats per day.

"The time that a heap requires depends upon its size, and upon the burning. Generally, about three weeks or a month is required for a large heap, of say 2000 cubic yards. No ballast is removed during the process. From the time of giving over feeding, the material may be removed in three days; but it is then still hot.

"The following is an estimate of the cost of production, per cubic yard :—

	s.	d.
Labour in excavating the clay . . .	0	6
„ moving and spreading . .	0	6
,, burning	0	6
Coal (say 10s. per ton), 2 cwt. . . .	1	0
	2	6

"If imperfectly burnt, the ballast has a tendency afterwards to return to its natural condition of clay. The colour should be, not pale red, but inclined to purple. When turned over, its degree of hardness may be inferred from the sound."

Concrete.

The nature of concrete, and the proportions in which the different materials should be mixed being explained in detail in the S. M. E. "Notes on Materials" (see also *Building Construction,* Part iii., Rivingtons), a few practical points only will be referred to here.[1]

Ingredients of Concrete.—For lime concrete it should be clearly defined in the specification that the proportion of lime is to be lime powder, either hot ground or slaked lime, and not left open to the contractor to measure it in the lump, if he chooses.

Portland cement, if too fresh, should be laid out on a dry floor, under cover, and turned over for a few days to cool, to guard against its blowing or swelling in setting. The aggregate must be perfectly clean, especially for cement concrete, dirt being fatal to its setting.[2]

If Thames ballast—that from above the bridges is the cleanest—be used, no sand need be added, as it is a mixture of shingle or water-worn stones with sand, in very good proportions. A good mixture is 1 coarse sand or grit to 5 of clean shingle.

For foundations, from 4 to 9 parts of ballast may be used to 1 of moderately hydraulic or stone lime, about 6 or 7 to 1 being most frequently employed; or 10 to 1 if Portland cement is used.

In breaking up stones for concrete, the pieces should be gauged through a 2-inch ring; such pieces, mixed with half their bulk of small stuff and sand, will be about the same as Thames ballast, but when used in thin layers, as in floors, where great transverse

[1] For specification to govern the execution of concrete in foundations, floors, and roofs, see Appendix V.; and for results of experiments on the strength of concrete slabs, and on concrete for fireproof structures, see Appendices I. and II.

[2] For specification for Portland cement, also Petrifite, see Appendix IV.

strength is required, a much smaller gauge-ring should be used, 1 to $\frac{3}{4}$ inch not being too small when the concrete will only be from 6 to 3 inches in thickness.

Broken bricks, burnt clay ballast, slag from furnaces, scoriæ from iron works, breeze or cinders, may be used instead of stone ballast; the lighter materials being preferable in such cases as concrete floors supported on girders, etc.; but when the material used is very rough and porous, the proportion of sand and cement should be greater, as a good deal is absorbed in the cavities of the material. For lightness, combined with the greatest transverse strength and resistance to fire, coke breeze concrete cannot be surpassed (see p. 326).

Mixing Concrete.—The best way of making lime concrete is by mixing together unslaked, or hot, fresh ground lime with sand and ballast, in the required proportions, on a stone, brick, or wooden floor, turning it over twice dry, and then, as it is shovelled to a third heap, adding, from the rose of a watering-can, sufficient water only to slake the lime, and make the ingredients cling together in a pasty mass, turning it over well as the water is added. Generally speaking it will take about three-fourths of a gallon to each cubic foot of ballast, but much will depend on the nature of the concrete and the dryness of the ballast, which ought always to be damp before mixing, but not actually wet. On the Chatham Dockyard Extension Works, 18 gallons per yard was considered the maximum which should be added.

Ground lime is to be preferred, but should a hydraulic lime, such as *blue lias* (pure or fat limes ought never to be employed), be used in the lump, it should, before mixing, be left to slake for two or three days—well covered up with sand, to promote the slaking by keeping in the heat. The whole should then be well turned over with a shovel, and time allowed before using, to insure the lime being thoroughly slaked, except in the case of cement concretes, which should be laid as soon as mixed. Roman cement concrete especially should be mixed rapidly on the spot, and laid at once, before it has time to begin to set.

Laying Concrete in Foundations.—The practice of throwing in concrete from a height, to consolidate the mass—which used to be insisted upon, even when staging had to be erected, and the stuff wheeled up to the required height at considerable expense —has now exploded. It should be brought on to the site, deposited and lightly punned or beaten down with wooden

rammers, but only just sufficient to bring the moisture to the surface; if rammed too much the cement comes up with the water. If, however, it is more convenient to tip the concrete into an excavation no sensible injury will be done to it.

The objection that, in falling, the heavier particles separate from the finer is, from the very stickiness of the mass, more theoretical than practical, and, at the most, applicable only to each separate barrow load tipped in, and not to the whole bed. Sliding it down a wooden shoot, however, should never be permitted, as the cement and small stuff cling to the sides and run down in a muddy slush; whilst the stones are shot out into a separate heap by themselves.

In ordinary foundations the concrete should be deposited in horizontal layers, about a foot thick, and care should be taken to cover any joints in one layer by the succeeding one, as the joint between two days' work is always a weak part; moreover, the last layer should be well wetted to insure a proper connection with the next.

In extensive foundations, with strong hydraulic lime or cement concrete, it is better to reduce the chances of any imperfect connection of the different layers, by making them 2 or 3 feet thick, each being completed as quickly as possible.

Estimating Materials for Concrete.—It is generally considered that the larger the stones used in making concrete, the greater will be the decrease of bulk in the materials after mixing. This may be as much as $\frac{1}{3}$, but with ordinary materials is about $\frac{1}{5}$; and if the lime is thoroughly slaked, so as to prevent any chance of expansion, a further decrease of about $\frac{1}{6}$ is said to take place in laying and ramming it.

This decrease of bulk must always be considered in estimating the materials required, and is best ascertained by actual trial with a small quantity of the materials intended to be employed. The following data may, however, be taken as a guide:—

A cubic yard, or 27 cubic feet of ordinary concrete, requires 34 cubic feet of gravel, sand, and lime. Therefore in the proportion of 6 to 1, a cubic yard of concrete will require 1·1 yards of gravel and sand to 3 bushels of lime, without taking into account any decrease of bulk from ramming.

For walls of houses 1 Portland cement to 8 aggregate may be used. For foundations 1 cement to 10 aggregate will be sufficient; and for floors 1 to 4, 5, or 6, according to circumstances.

Detail of 1 yard of Portland cement concrete in walling, about 8 gravel to 1 cement—

	s.	d.
1·1 yards clean gravel	4	5
$2\frac{3}{4}$ bushels Portland cement at 2s. 6d. . .	6	10
18 gallons water, cost varies from . .	0	0
Labour mixing and depositing . . .	2	6
,, fixing and shifting appliances . .	0	9
Use and depreciation of ditto . . .	0	6
Total, including 10% profit . .	15	0

For large quantities and under favourable circumstances, as regards prices of cement and gravel, the cost may be much lower than above. The 12 to 1 Portland cement concrete used for the body of the Chatham new dock walls, made by free labour, cost just under 7s. per yard; see par. 684 *R. E. Aide Mémoire,* where the relative prices of different descriptions of concrete are given, also in par. 682 the crushing strengths of Portland cement concrete are given.

Measuring Concrete.—Concrete, if under 1 foot thick, is usually paid for by the yard super, according to the nature of the materials, and if over 1 foot thick, by the yard cube, with so much extra for hoisting to any height.

BRICKLAYER.

The bricklayer performs all kinds of work in which burnt clay, in the form of bricks, tiles, and pipes, is the principal material employed; as in building brick walls and arches; setting boilers, grates, etc., in brickwork; paving with bricks and tiles; laying brick drains or stoneware pipes; tiling roofs, etc.; as well as all the necessary work connected with the same.

Principles of Bricklaying.

The bricklayer, unlike the mason, has the advantage of building with materials of a uniform size and shape (ordinary London bricks are called $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$ inches, though, as a rule, they only run $8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{1}{2}$ inches), hence his work is always *coursed,* or built in continuous *courses* or bands, of a height equal to the thickness of the bricks employed, or their breadth if placed on edge, to which may be added the thickness of one mortar joint

between the courses; consequently with ordinary London bricks each course may be taken as 3 inches deep, giving four courses to the foot as a rough and ready means of calculating heights in brickwork.[1]

The *beds,* or upper and lower surfaces of the bricks in each course, should be as nearly as possible perpendicular to the direction of the pressure they have to bear.

Bond in Brickwork.—As the strength of a wall could not, with safety, be allowed to depend solely upon the firmness with which the bricks are cemented together, each brick is so placed over others in the course below as to tie two or more together, by means of the transmitted weight due to the mass of walling above and whatever is carried upon it, and at the same time to distribute the effects of a weight concentrated upon any one brick over an area increasing rapidly as it descends to the foundations. The particular mode of arranging the bricks in each *course,* in order to make them *break joint* with those in the course above and the course below, and so to give them a good hold, as it were, of each other, being termed the *bond.*

Headers and Stretchers—Heading and Stretching Courses.—In order to obtain a proper bond in walls over half a brick thick, the bricks are placed in different ways, some being laid as *headers,* across, or with their ends parallel to the face of the wall; and others as *stretchers,* in the direction, or with their sides parallel to the face, of the wall; and when the courses appear on the face of a wall as continuous lines of headers and continuous lines of stretchers, they are called respectively *heading* and *stretching courses.*

Each brick should be as far as possible from coinciding in position with any of those on which it rests. This is done by making the bricks in one course lap over, or cover, the joints in the course below, each brick being made to rest on two, three, or four bricks in the course below; and that bond is the strongest which leaves the fewest joints uncovered. Fig. 8 shows, in elevation, a piece of a $4\frac{1}{2}$-inch brick wall, in which there is no *bond,* so that a weight resting on any single brick has to be borne

[1] The largest building bricks are made at Elgin, in Scotland, $12 \times 6 \times 3$ inches, and are used for partitions; the smallest are the Athy bricks in Ireland, $8 \times 3\frac{3}{4} \times 2\frac{3}{4}$ inches; whilst special clinkers for paving run as small as $6 \times 2\frac{1}{2} \times 1\frac{3}{4}$ inches. Irregular sized lumps for irregular coursed work, similar to Fig. 84, are made at Blenheim, at Messrs. Bolton and Co's. Brick Works.

by an area of foundation equal only to the area of a single brick; but if the same number of bricks are placed so as to break joint, as in Fig. 8*a*, the weight not only helps to tie them together, but is distributed over a foundation area of five bricks instead of only one.

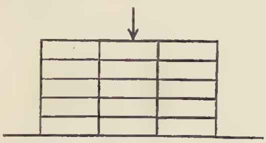


Fig. 8.

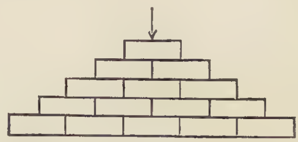


Fig. 8*a*.

Lap—Perpends.—The *lap*, or horizontal distance between the vertical joints in two contiguous courses, must be as great as possible; but a brick being half as broad as it is long, the *lap* cannot exceed $2\frac{1}{4}$ inches or a quarter brick, except in a wall $4\frac{1}{2}$ inches, or only half a brick thick; which is never built except as a partition wall, or as part of a hollow wall. Nor can more than the thickness of one course separate the vertical joints, which should fall perpendicularly over each other in every alternate course; or, in technical phraseology, the *perpends* should be truly kept.

Bond in Interior of Walls.—In judging the strength of any description of bond, the interior as well as the exterior of the wall must be examined; for a wall may show a good bond externally, and yet, from a faulty internal arrangement, it might be liable to split in two longitudinally. This is shown in Fig. 9, which represents part of a two-brick wall looking precisely similar on face, but very differently built in the interior, the upper part showing no internal bond whatever, owing to the bricks in the interior being placed as stretchers; for which reason, except under special circumstances, no stretchers should ever be used in the interior of brick walls.

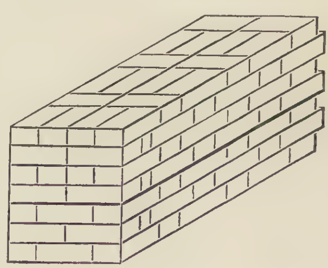


Fig. 9.

Queen Closer.—The term *queen closer* is applied to a brick cut longitudinally in half, so as to be half its proper breadth, and built in as a half header, in order to insure a bond. As this, however, is not an easy operation, a brick is usually cut trans-

versely into two halves or *bats* (if broken bricks are not to hand), each of which can then be cut into two quarter bricks or half *closers*, which, when placed in the wall end to end, constitute a *closer*.

Three-quarter Bat Closer.—A brick with a quarter of its length cut off is termed a three-quarter *bat*, and is sometimes used as a *closer*.

King Closer.—Bricks notched out, as at A, Fig. 10, or as

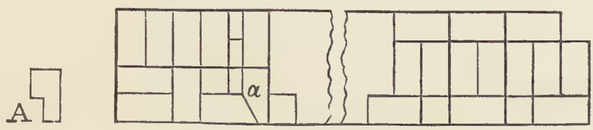


Fig. 10.

shown at *a*, in order to obtain a better bond in closing up to door, window, and other openings, are called *king closers*.

Use of Closers.—*Closers* are used in every alternate course at the vertical angles, or quoins, of brick walls, whatever the bond may be. They are required to prevent the vertical joints from coinciding, or, in other words, to start the bond from, or close it on, any vertical angle. They extend through the whole thickness of the wall, and, in the case of *queen closers*, show on the face of the wall as the last brick but one in every alternate course, so as to allow of the quoins being composed of whole bricks. Without closers—bricks being twice as long as they are broad—the vertical joints would, at either 1 or $1\frac{1}{2}$ brick intervals, run unbroken from top to bottom of the wall, leaving no longitudinal tie in the wall beyond that due to the mortar.

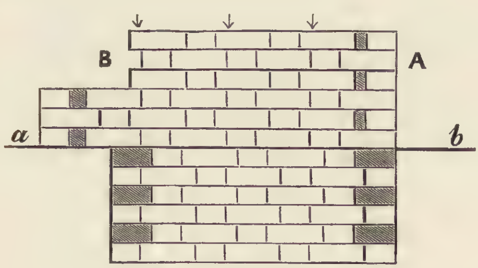


Fig. 11.

Fig. 11 shows part of a wall in elevation, started from A, where the small dark bricks, in the portion above *a b*, are the

queen closers, without which the joints, where indicated by the arrows, would coincide from top to bottom of wall. At B part has been finished to a vertical line by putting in queen closers, whilst the upper part is left *toothed*, as if it were to be continued along. Below the line *a b* the shaded bricks are three-quarter bats used as closers, but they are rarely adopted in practice, probably because damaged and broken bricks are more easily used up as queen closers.

In order to see clearly how the closers should be arranged, say at the angle of a brick wall, let us suppose two courses of bricks to be placed as in Fig. 12*a*, where, as will be seen at once, there

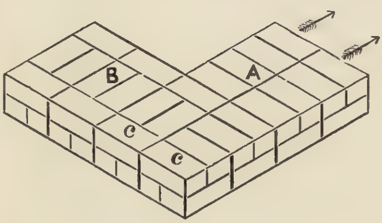


Fig. 12*a*.

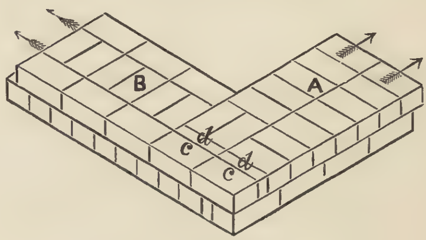


Fig. 12*b*.

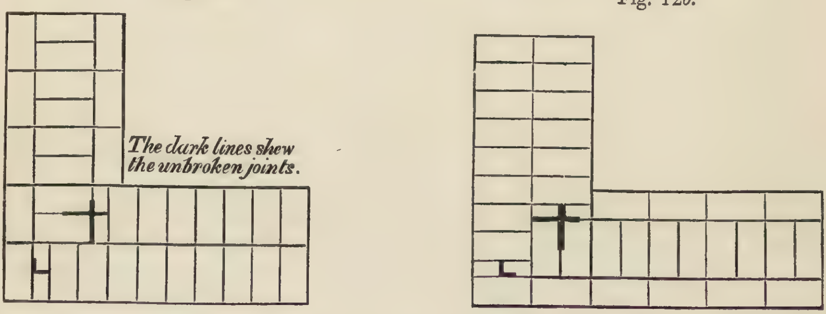


Fig. 12*c*.

is no longitudinal bond, for the cross joints, at one brick intervals, would run unbroken from top to bottom of the wall; but if, leaving the end bricks *c c* untouched, we slide the rest of the course A the distance of a quarter brick away from the angle, in the direction of the arrows, and in the vacant space so made insert the closers *d d*, Fig. 12*b*, we shall then have broken the joints, and so obtained a bond in the wall A; and in the same way, by

sliding the lower course of the two in the wall B in the direction of those arrows, we can obtain a like result, and both walls will then be bonded, as in Fig. 12*b*.

The whole bricks are left at the ends of the courses so as not to weaken the angle of the wall, and for the same reason the queen closers are generally distributed in echelon through the wall, as shown in successive courses, on plan, in Fig. 12*c*. It is clear, therefore, that when closers are required, they must in all cases run through the whole thickness of the wall, and appear in every alternate course, close to the angle, on each face of the wall. As may be seen by referring to Figs. 12*a*, 12*b*, 12*c*, the same effect would be produced by using three-quarter bats at the ends of the stretching courses, instead of the queen closers in the heading courses.

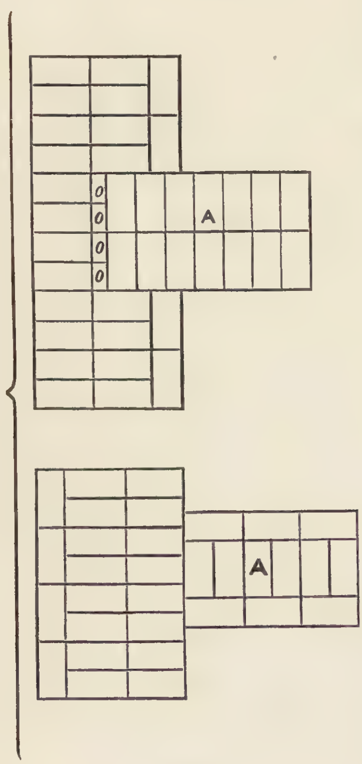


Fig. 13.

In the junction of party with main walls, closers are required in every alternate course, to insure a quarter brick lap, or toothing, of one wall into the other. The way in which this is done is shown in two successive courses in Fig. 13, in which A is the party wall, and *o o* are the closers inserted in every alternate course.

It has been proposed (*vide Student's Practical Guide to Measuring*, by Edward Dobson) to do away with the use of small pieces of brick as closers, and to adopt special closing bricks of a larger size, in order to impart greater solidity to the ends, angles, and junctions of walls. Such a practice is, however, never likely to become general, for the simple reason that a wall, built with the ordinary closers, shows no special signs of weakness where the closers occur; therefore there cannot be any object in trying to find a remedy for nothing but

an imaginary evil. Moreover, extra expense and trouble are entailed by special closing bricks, whilst the bricklayer objects to them on account of the difficulty of laying them with one hand; a consideration which, involving, as it does, the question of time, has practically limited the size of bricks for building purposes as effectively as if the old restrictive Act of Parliament still imposed heavy duties on bricks exceeding a certain size.

Different kinds of Brick Bond.

There are two kinds of bond commonly used in England, viz., *English bond* and *Flemish bond.*

English bond.

Principles of English Bond.—The descriptions of English bond, given in many architectural books, are not to be relied on. One of the few books in which it is rightly described is in a valuable treatise on brickwork, by the late Sir Charles Pasley, K.C.B., R.E., entitled, *A Course of Practical Architecture, compiled for the use of the Junior Officers of the Royal Engineers,* where the errors into which various authors have fallen on this subject are carefully exposed, and will not, therefore, be dwelt on here.[1]

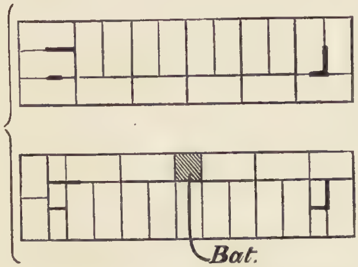
True English bond fulfils the three following conditions:—

1*st.*—*A wall built in English bond shows, both on its face and back, periodical heading and stretching courses;* that is to say, all headers or all stretchers in each course. The heading and stretching courses are almost always laid alternately, hence it is generally said to consist of *alternate heading and stretching courses;* but, strictly speaking, the nature of the bond depends on the arrangement of the bricks in each course, and not upon the alternation of the courses. Figs. 12*c* and 13 show bricks laid in English bond. In all walls involving half a brick in their thickness, such as $1\frac{1}{2}$, $2\frac{1}{2}$, etc., the courses which show as heading courses on the face of the wall show as stretching courses at the back, and *vice versâ* (*vide* Fig. 14).

2*d.*—*No stretchers should be used except those seen on the face of the work,* however thick the wall may be. The result of using stretchers in the body of the wall is seen in the upper part of

[1] Also correctly described in *Notes on Building Construction,* part i, published by Rivingtons.

Fig. 9; consequently, when the heading and stretching courses alternate, there is, in thick walls especially, a deficiency of stretchers or longitudinal ties.[1] To remedy this, one heading to two stretching courses may be laid; and in factory chimneys, three or four courses of stretchers to one of headers are frequently used to tie the work together, and prevent it splitting; but in special cases, such as in circular chimneys, stretching courses may with advantage be continued through the whole thickness of the work, in order to tie it more securely together.



The dark lines are unbroken joints.

Fig. 14.

3*d*.—*The bricks in the same course should not break joint with each other,* but the transverse joints should run unbroken from the face to the back of the wall. In this most books err, as it looks, taking each course separately, a better arrangement to break the joints in each course; but, by so doing, a large number of vertical joints must run unbroken from top to bottom, in the interior of the wall. Fig. 15 shows the bricks breaking joint with each other in the same course, the dark lines being the unbroken joints — which are, moreover, transverse joints, thus adding greatly to the weakness of the wall, owing to the deficiency of longitudinal ties, as already explained—whilst in Figs. 12*a*, 12*b*, 12*c*, where the transverse joints run, at half and one brick intervals, right across the wall, there are no vertical joints left unbroken. This rule applies to good work, but in thin, badly built house walls, with little or no mortar in the interior, the wind and weather are kept out better by breaking the joints of the bricks in each course.

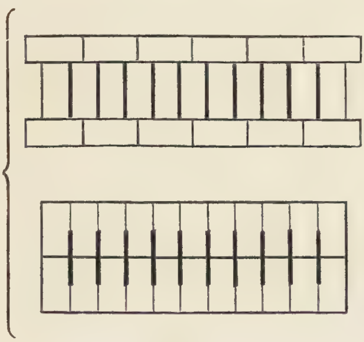


Fig. 15.

In English bond there are twice as many transverse joints

[1] In $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3 brick walls there are, respectively, only $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, and $\frac{1}{5}$ as many stretchers as headers.

in a heading as there are in a stretching course; therefore, in laying the headers, care should be taken to make these joints as thin as possible, for if two headers are laid so as to occupy more space than one stretcher, the quarter-brick lap cannot be maintained, the perpends will no longer be true, and the strength of the wall may be seriously injured.

In walls built in English bond, involving half a brick in their thickness, both sides are not equally regular; a bat having to be used in the stretching courses; therefore, in good work, that side of the wall should always form its face in which the closers occur in the heading courses. This is shown in Fig. 14, which gives plans of two successive courses, the opposite ends of the wall being closed up differently.

Except the closers, none but whole bricks need to be used in building in English bond.

St. Bartholomew's Hospital, near Fort Pitt, Chatham, is a good example of brickwork built throughout in English bond.

English Cross Bond is a variety of English bond much used in Holland (see *Builder*, 23d June 1883); its name being suggested by the chequered appearance of the surface, on which the vertical joints arrange themselves into St. Andrew's crosses, as shown by the dotted lines on Figs. 16 and 17. It only differs from ordinary English bond in the stretchers of the successive stretching courses breaking joint with each other on the face of the wall, as well as with the headers of the adjoining heading courses; this being effected by shifting every alternate stretching course half a brick away from the end stretcher, or, in other words, by inserting

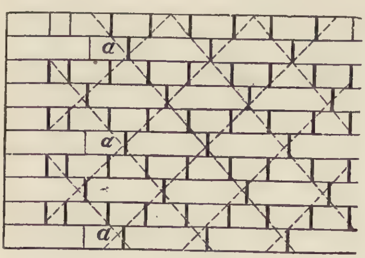


Fig. 16.

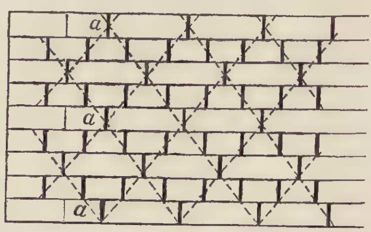


Fig. 17.

a header next to the end stretcher of each alternate stretching course, as shown in elevation in Figs. 16 and 17, where *a a* are the inserted headers.

This form of English bond gives greater transverse strength to the wall, and considerably improves its appearance.

The Dutch generally use three-quarter bat-closers, as in Fig. 17, in the stretching courses, in place of closers in the heading courses.

Scotch or Garden-wall Bond.—Three or four courses of stretchers to one of headers, as used in 9-inch walls, when required to show a fair face on both sides, forms a variety of English bond known as *garden* or *garden-wall bond*, and also as *Scotch bond.* In some localities this bond is known as *common bond,* the term "garden bond" being applied to 9-inch walls showing about three stretchers to one header in each course, which is really a variety of "Flemish bond" described below. Ordinary bricks vary so much in length that it would not be possible, in a one-brick wall, to work the headers to a fair face on both sides; one face, at least, would appear very rough and uneven, unless all the headers were picked of, or reduced to, the same length. However, by using several stretching courses—in which the bricks can be adjusted to a fair face on both sides by varying the width of the joint in the centre of the wall—the number of headers required is greatly reduced, and, consequently, the labour of picking them.

Flemish Bond.

Double Flemish Bond.—*Flemish, or double Flemish bond,* as it is sometimes called, *shows, on both faces of the wall, alternate headers and stretchers in each course,* so that every course presents the same appearance, as seen in Fig. 11. It is not so strong as English bond, since many of the vertical joints coincide in the heart of the wall, and it necessitates the use of a large number of bats, in all walls an odd number of half bricks in thickness.

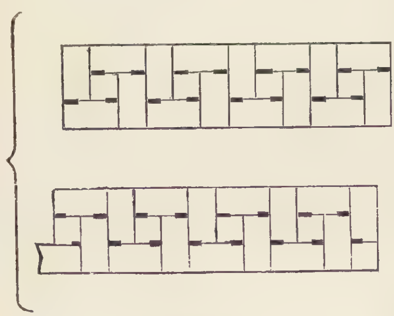


Fig. 18.

This may be seen by looking at Fig. 18, which gives plans of two successive courses of Flemish bond in a $1\frac{1}{2}$-brick wall—the dark lines showing the unbroken joints running down through the body of the wall.

The large proportion of bats and unbroken joints, which occur

in a $1\frac{1}{2}$-brick wall built in Flemish bond, is shown in two successive courses in Fig. 18, in which the bats are placed, as they ought to be, in the centre of the wall.

Single Flemish Bond.—*In single Flemish bond only one face of the wall shows alternate headers and stretchers in each course,* the rest of the wall being built in English bond. It is very generally used when it is desired to combine the strength of the latter with the appearance of the former.

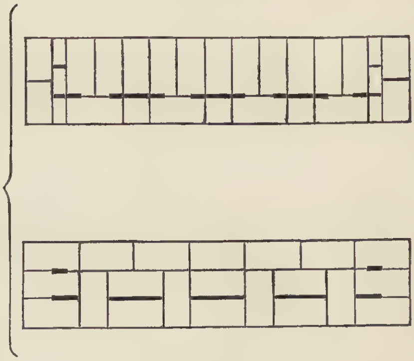


Fig. 19.

Fig. 19 represents two successive courses of a $1\frac{1}{2}$-brick wall built in *single* Flemish bond, the dark lines showing unbroken joints; in which case bats must appear on the face of the wall, unless $\frac{3}{4}$ bats were used, as at the ends of the upper plan, which is never done in practice.

Fig. 20 gives plans of successive courses of a two-brick wall built in single Flemish bond, the bats in the portion A being all on the face of the wall, as would generally be the case if superior facing bricks were used, unless it were prevented by careful supervision; whilst at B they are all in the interior of the wall, which is at once seen to be the best position for them, since the unbroken joints, instead of being all together, are evenly distributed along two separate lines, throughout the length of the wall. Hence, whenever Flemish bond is used, it should be specified that "no bats or *false headers* will be allowed on the face of the work, except when unavoidable (as in a *single Flemish* $1\frac{1}{2}$-brick wall, as explained above), and only where absolutely necessary in the body of the wall."

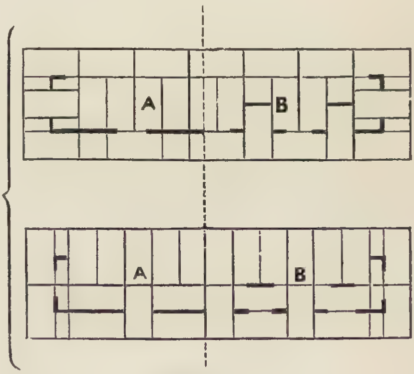


Fig. 20.

Fig. 10, p. 30, shows two successive courses, one on each side of the opening, of a two-brick wall built in single Flemish bond. It may be seen to advantage at the Garrison Gymnasium, Chatham, the outer face of which is Flemish bond, and the inner English bond.

Single Flemish bond forms a fertile source of unsound work. It has led to a practice of using better bricks and thinner mortar joints in the facework than in the rest of the wall, which frequently gives rise to unequal settlement; in addition to which, unless carefully watched, the bricklayers will economise the superior bricks by cutting the greater number of headers in half, and using bats or *false headers*, thus destroying the bond between the face and back of the wall, as has been already shown.

Again, the thickness of the courses in the face, when superior bricks and finer joints are made use of, will rarely coincide with those laid with coarser mortar joints in the rest of the wall; consequently, seven or eight courses of facework may only occupy the height of six or seven courses of the rest of the work, as shown in Fig. 21; in which case no true headers can be used to tie the face to the back of the wall, except at intervals, where the face and back happen to run up to one level. Moreover, even the tails of these few headers are liable to be broken off by an unequal settlement taking place, in consequence of the different number and thickness of the joints in the face and back of the wall. To remedy this defect, the facing bricks should be slightly thicker than the rest; but, even then, the coarser joints in the body of the wall will settle more than the facework, so that bricks and joints of a uniform thickness, throughout the whole body of the wall, ought to be insisted on.

Fig. 21.

English superior to Flemish Bond.—English bond should always be used in preference to Flemish bond where strength is an object of importance, but when the external appearance of Flemish bond is desired, single Flemish bond should be used for all walls over $1\frac{1}{2}$ brick thick.

The sole merit of Flemish bond consists in its appearance, which it has been, for a long time past, the fashion to consider preferable to that of English bond. It has popularly been supposed to have been introduced into England from Flanders, but no traces are, I believe, to be found of its ever having been in common use out of England.

Special Bonds.

The following are some modes of laying bricks, occasionally resorted to under special circumstances:—

Diagonal Bond.—*Diagonal bond* consists of *diagonal courses* introduced here and there to increase the strength of thick walls, by making up for the deficiency of stretchers in the interior.

The bricks, between the facing bricks, are laid diagonally, or at an angle of about 35° to the face of the wall, as shown in two successive courses in Fig. 22. This may be done at regular

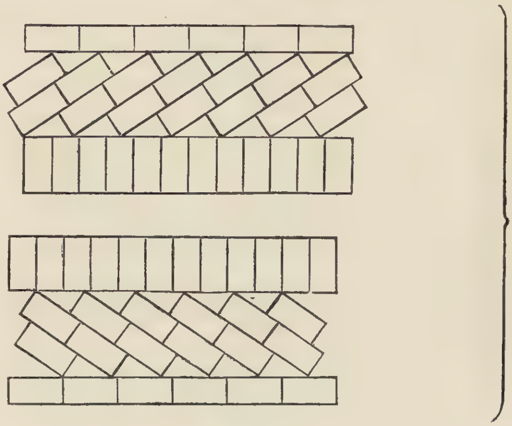


Fig. 22.

intervals of three, four, or more courses, either in single courses or two courses raking in opposite directions, one on the top of another; in no case should a diagonal course rake in the same direction with the one previously laid.

They are only used with English bond, on account of the cutting which would be required in working them into a Flemish bond facing.

No particular advantage is gained by using diagonal courses in walls less than three bricks thick. A two-brick wall is the thinnest in which it is possible to employ them, and then only in the stretching courses.

Diagonal courses were freely used in building the earlier dock walls of the Chatham Dockyard Extension Works.

Herring-Bone Bond.—*Herring-bone bond* consists of *herring-bone courses,* which are somewhat similar to diagonal courses; the

only difference being that the bricks in the same course on opposite sides of the centre line between the facing bricks rake in different directions, as in Fig. 23. It is very seldom employed,

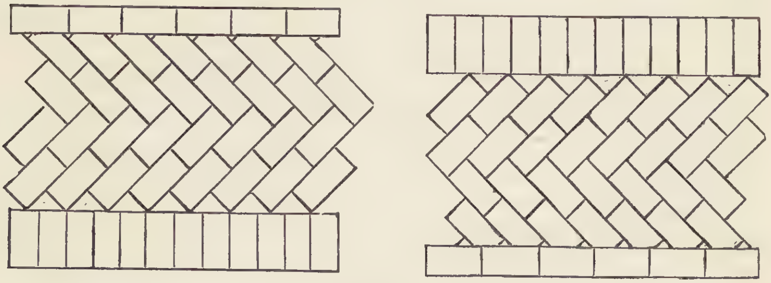


Fig. 23.

except in paving, and cannot be used in walls under three bricks thick, and in three-brick walls only in the stretching courses.

Header Bond.—*Heading* or *header bond* is a description of bond in which all the bricks are laid as headers. It is only allowable in working round sharp curves, or *quick sweeps* as they are called, when a brick laid as a stretcher, without having been *gauged,* or cut and rubbed to the required curve, would break the even sweep of the facework; and even then the sides of the headers must be roughly cut so as to radiate from the centre of curvature. For straight work it is very weak, both in reality and in appearance, and, in walls over one brick thick, necessitates a row of bats in every alternate course. It may be seen to advantage in the streets of Poole, in Dorset, where some enthusiastic admirers of heading bond have indulged their taste *ad libitum.*

Stretcher Bond.—*Stretching* or *stretcher bond* is a description of bond in which all the bricks are laid as stretchers, and is therefore only applicable to half-brick walls, such as are used for thin partitions, chimneys, and the thin skins of hollow walls. From its constant use in the construction of flues it is also known as *chimney bond.*

Special arrangements of bricks in footings, piers, string and corbel courses, etc., will be explained when treating of those special parts.

Execution of Brickwork.

General remarks on building brick walls.

It may be thought that the foregoing remarks on brick bond inculcate a degree of perfection which is practically unnecessary;

the answer to this is that a good bricklayer, as well as a good superintendent, ought thoroughly to master all the principles upon which perfect brickwork depends, whilst the standard of perfection to be maintained in any given work must depend upon the circumstances of the case; if, for instance, there is any risk of unequal settlement, or of the brickwork being exposed to severe strains or shocks, as in revetment walls to fortifications, docks, etc., the most perfect bond is essential to strength, whilst to the want of it may frequently be traced the numberless cracks which so often disfigure brick buildings.

On the other hand when the foundations are good, and the walls much thicker than is requisite on the score of strength, perfect workmanship is not so necessary, and weaker descriptions of bond may be used for the sake of appearance, or even a hollow space left in the body of the wall for the sake of dryness and warmth.

Again, if the work is carefully executed in good hydraulic mortar or cement, with sound well wetted bricks, the presence of a few unbroken joints in the body of the work, or even the insertion of a few bats, broken bricks, or false headers, provided the whole is built up solid, and the joints completely filled in with mortar or cement, is not of so much consequence as would at first sight appear, as the whole sets as one solid mass of what might be termed brick concrete; at the same time, it would not do to relax the strictness of specifications, which are framed so as to give the superintending officer power to stop any really unsound work, whereas it would be impossible to specify to what extent departure from theoretically perfect work should be permitted.

Apart, however, from the bond of the bricks, there are practical details connected with the execution of brickwork which have to be carefully attended to, such as that walls are carried up perfectly plumb, or vertical, and each course laid level in every direction; except when a wall is built to a *batter* or inclined face, in which case the bed-joints are perpendicular to the face of the wall. In the footings of a wall this should be specially attended to, as any irregularity there will be carried up into the superstructure, and can only be afterwards rectified by using a greater or less amount of mortar in the different parts, which will lead to the wall yielding unequally to the weights brought upon it.

Walls to be carried up evenly.—The walls of a building

should be carried up evenly, no part being allowed to be run up more than 3 feet higher than the rest, otherwise unequal settlement and cracks will be the result. Moreover, the mortar joints in the higher part setting before the rest is added to it, the connection between the two parts will be rendered faulty from the last laid work settling away from that first built. In all cases the ends of the part first built should be stepped, or *racked* back, and not run up vertically with only toothings left for connecting the rest of the work.

Even after the completion of the walls they are very likely to crack, if unequally loaded, before the mortar has had time to harden sufficiently to resist the pressure.

Joining New to Old Work.—In making additions to an old building a *chase* or groove should be cut in the old wall, to connect the new work to the old, and to allow of its settling independently. If the new work is toothed in it should be built in cement, which sets rapidly, and so prevents any settlement, provided the foundations do not give.

Birdsmouth—Squint Quoins.—When two walls, not at right angles to each other, meet, the corner bricks or stones have to be cut to the required angle; when a re-entering angle the cutting is termed a *birdsmouth* cutting, and at a salient angle the splayed quoins are called *squint quoins.*

Brickwork and Frost.—Brickwork should never be carried up in frosty weather, or when there is a chance of frost occurring before the walls are sufficiently dry not to be affected by it. But should it be necessary to go on with the work in the intervals between the frost, the walls must be covered with straw, the weather-boards placed above it to throw off the rain or snow. The quicker the mortar sets the less chance will there be of the work being injured. It is said that frost will have no effect upon mortar made up as follows, and used hot—1 pint of linseed oil containing 1 lb. of alum well mixed in with 1 bushel of unslaked lime to 3 of sharp sand.

Brickwork and Wet.—Wet, without frost, will not injure brickwork, but rather improve it, by effectually wetting the bricks, if the joints are properly flushed up solid with mortar, leaving no hollows to hold water; the top of the wall should, however, be covered with boards to act as a coping and keep the wet from running down and discolouring the face of the work.

Bricklayer's Tools.—In addition to his *trowel* and special tools referred to elsewhere, the bricklayer uses the following in laying out his work, etc. :—

Plumb-rule, or thin wooden rule, 4 to 7 inches wide, with a

line and plummet fixed at one end, and swinging down its centre; used to insure the perpendicularity of the walls.

Level, or straight edge of wood, about 10 or 12 feet long, used with a spirit-level, or made like an inverted T, with a line and plummet swinging from the vertical arm; used to try the level of the walls.

Lines and pins, consisting of two iron pins, with about 60 feet of fine cord attached to and wound round them.[1] To prevent constant recourse to the plumb-rule and level, the bricklayer, on clearing the footings of the wall, will build up bits of six or eight courses in height, called *perpends*, at the quoins or external angles, and at intervals along the wall, carefully plumbing and levelling them across from one to the other; these form gauges, to which he works the intervening parts of the courses, by means of the line tightly strained between the perpends, the pins being stuck into the joints at the upper and outer angles of the gauge bricks in the next course to be laid. To prevent sagging, if the line be long, it must be carefully propped at intervals, the bricks used for this purpose being called *tingles*.

After carrying up three or four courses with the line the work should be proved with the *level* and *plumb-rule*. A smart tap with the handle of the trowel will generally adjust any brick that may be out, without injuring the work while it is so green.

Gauge moulds or *templets*, and *battering rules*, for laying out sloping, or *battering*, and curved work, where the lines and pins cannot be used. They are made of wood, cut or formed to the required curve or batter, and fitted with a plumb-line.

Compasses or *trammels*, which are rods of iron or wood, with sliding pieces, fitted with points capable of being fixed at any distance apart; used in setting out curved work.

Wooden *squares* are employed in setting out right angles; and *bevels*, capable of being set to any angle, or special *templets* for acute or obtuse angles.

The *bricklayer's hammer*, which has an axe or cutting edge at one end, together with *chisels* and the *mash hammer* for striking them, are used for cutting chases and holes in walls.

The *crow* or *setting bar* of iron, about 3 feet long, and pickaxe, are used for breaking and cutting through walls, and moving and setting heavy weights.

[1] Old Roman bricklayers' pins have been found with eyes at the heads, through which to strain the line accurately over the axis of each pin.

Tools for R. E. Companies.—Patterns of the different tools for each trade, authorised for the use of R. E. Companies, may be seen, *marked with their names,* in the R. E. Institute, Chatham. They frequently differ, both in size and pattern, from those employed in civil life, as they are designed with a view to economy of weight and space, and include only such tools as are necessary to the execution of ordinary descriptions of work.

Bricklayer's Scaffolding (see Fig. 24).

If a wall is of no great height the upper part may be completed by the aid of a few planks raised on bricks or wooden trestles; but in building high walls for houses, etc., a regular staging, or *scaffolding,* has to be run up as the work advances.

The bricklayer's scaffold consists of *standards, ledgers* or *runners, putlogs, scaffold boards* or *sheeting,* and *bracing.*

Standards.—*Standards* are upright poles, generally of spruce fir, 20 to 50 feet long, and about 5 to 7 inches diameter at the butts; those under $2\frac{1}{2}$ inches at tips being termed *rickers,* and running about 22 feet long. They are firmly fixed in the ground, about 4 feet 6 inches from the wall, and from 10 to 12 feet apart; but for temporary purposes, or where it is not convenient to sink them, a firm base may be obtained by standing the butts in tubs filled in with earth, rubbish, or mortar. When greater lengths are required they may be pieced out by fastening two or more poles together, tip and butt, the lashings being tightened by wooden wedges.

Ledgers.—*Ledgers* or *runners* are poles placed horizontally, and parallel to the wall, being secured to the standards on their insides, next the wall, by rope lashings, tightened by wooden wedges. They support the putlogs, and should not be placed at greater vertical intervals than 3 feet 6 inches.

Putlogs.—*Putlogs* are cross-pieces, usually of sawn birch 4 by 3 inches, and 6 feet long, placed from 4 to 6 feet apart, according to the length and strength of the boards they are intended to carry. One end rests on the wall, on the middle of a stretcher—so as to occupy the place of a header, which is inserted after the work is done and the scaffold struck—and the other end rests on a ledger, and sometimes, for stiffness, is lashed to it.

Sheeting.—*Scaffold boards* or *sheeting* are the boards forming

the gangway, and consist of $1\frac{1}{2}$ to 3-inch deals, generally iron hooped at the ends, to prevent their splitting.

Braces.—*Braces* are poles lashed diagonally outside and across

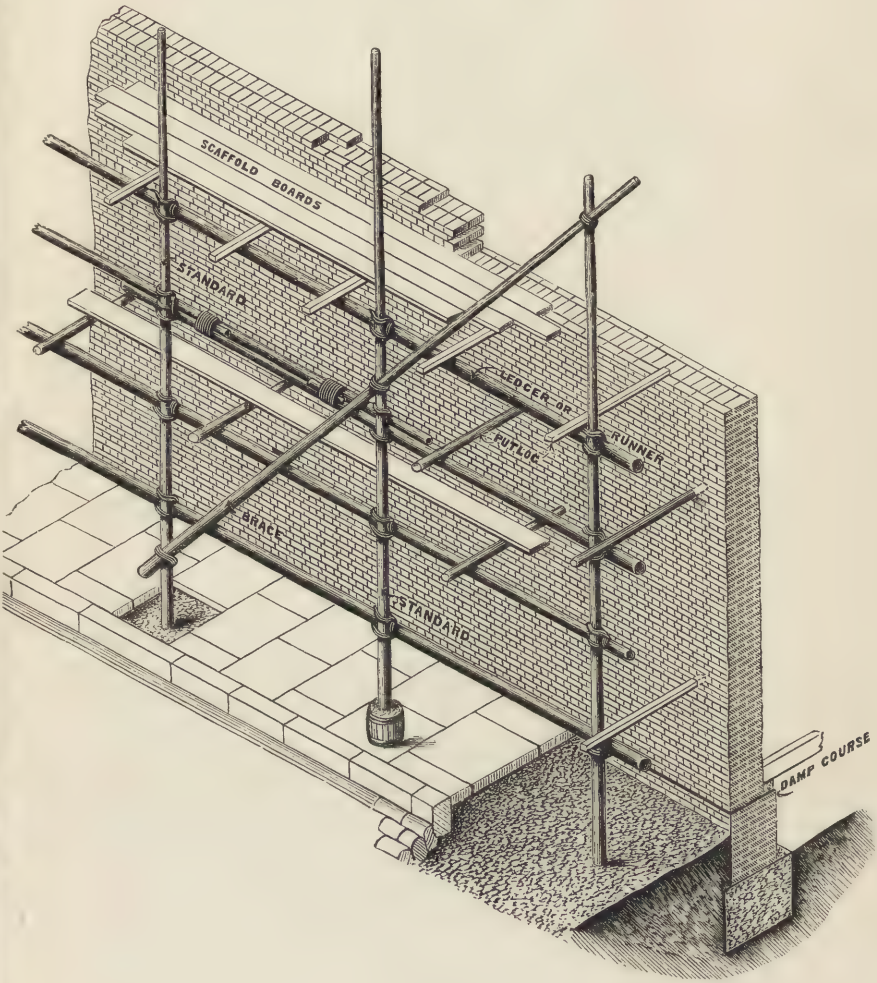


Fig. 24.

the standards and ledgers, to stiffen the scaffolding, when run to any great height.

Hodmen and Hods.—The bricklayer stands on the scaffold, and the materials are brought to him by labourers called *hodmen*, in *hods*, or hauled up in baskets and buckets by means of a pulley,

wheel, and fall. The *hod* is a wooden box, closed at one end and open at the other, capable of holding twenty bricks; the ordinary load, however, being sixteen walling or twelve facing bricks (more care having to be taken of the latter), or two-thirds of a cubic foot (nearly half a bushel) of mortar. It is fixed at the top of a long handle or leg, upon which it is supported during the operation of filling and unfilling, and by which the *hodman* steadies it when carrying it upon his shoulder.

Mortar Boards.—The mortar is usually placed on ledged boards, about 3 feet square, at convenient distances along the scaffold, and the bricks strewed between them, leaving a clear space for the bricklayer to walk along by the side of the wall.

Erecting Scaffolding.—The bricklayer begins laying his work from the extreme left of his course, working to the right, course after course, until the work gets too high, when another ledger must be lashed to the standards, and fresh putlogs and sheeting laid at the higher level; the lower ledgers, and most of the putlogs, being left to insure stability. The vertical distance from ledger to ledger should never be allowed to exceed 3 feet 6 inches, in order to guard against *overhand* work, or bricks being laid at too great a height to insure good workmanship.

The bricklayer's labourers are employed in erecting and striking the scaffolding. They should keep up a steady supply of materials to the bricklayer, without ever loading the scaffold unnecessarily, both on its own account, as well as to prevent any injury being done to the *green* brickwork, which has to support about half the weight on the scaffold.

Hiring Scaffolding, etc.—The cost of hiring scaffolding, tackle, ladders, mortar mills, and builder's plant of all kinds, is given in Kelly's, Laxton's, or other *Price Books*, as well as in the War Department Schedules.

Laying bricks in mortar or cement.[1]

Object of Mortar.—Bricks are bedded in mortar for the following reasons :—

1*st.*—To guard against fracture, by insuring an even distribution of the weight.

2*d.*—To render the joints proof against wind and rain; for which purpose all the spaces between the bricks should be well *flushed up*, or filled in solid with mortar.

[1] Specification for Lime, Cement, and Selenitic Mortars, see Appendix III.

3d.—To unite the bricks together, so as to form one solid mass. To perfectly attain this object the mortar employed, besides thoroughly filling the joints, should be capable of setting so as to be equal to the bricks, intended to be cemented together, both in its cohesive, adhesive, and crushing strength.

Laying Bricks.—In laying bricks the only tool required by the bricklayer is the *trowel*, which he uses for taking up and spreading the mortar, as well as for roughly cutting bricks to the required shape, as in making closers, etc.

The ordinary practice in laying bricks is as follows:—

In laying the facing bricks the bricklayer takes up some mortar, throws it on the last laid course, and spreads it out with the point of his trowel to form a bed for the next brick; whatever projects on the face of the work he then strikes off, and catches on the flat of his trowel, scraping it off against the vertical angle of the last laid facing brick, and this is too often all the mortar applied to the side joints of the facing bricks, instead of their being filled up solid. Having done this, he presses the next face brick into its place, carefully adjusting it with his hand, or by tapping it with the edge of the blade, or the handle of his trowel—a process in which a careless workman will often break from one-sixth to one-fifth of the headers, by giving too hard a blow.

The mortar squeezed out of the joint, in pressing the last brick into its place, is then struck off, and the joints, after the mortar has stiffened a little, are neatly *drawn* or *struck*, by drawing the point of the trowel along them—unless the wall is to be pointed after completion, or to be plastered; in the latter case the mortar is generally left to project, in order to form a key to hold the plaster, as at *l*, Fig. 26; whilst in the former case the mortar is scraped out of the front of the joints, leaving a hollow key to receive the *pointing*, as at *m*.

Scamping Brickwork.—The interior of the wall is too often filled in anyhow, with bats or any rubbish to hand, bats even being used as *false headers* on the face of the wall. Such work is then covered up by *flushing* the joints, or dashing mortar on them, and smoothing all over with the trowel and a little more mortar, which gives a nice smooth appearance to the unpractised eye, but may easily be detected by taking a trowel and plunging it here and there into the heart of the wall.

By the process just described, the side joints are not usually filled beyond 2 inches from the face of the work, open joints are left in

the heart of the wall, which will not be proof against wind or rain, and the bricks are not properly cemented together. It is necessary to guard against this system of *scamping* the work, and to see that the bricks are thoroughly bedded, and the vertical joints filled up solid with mortar, not merely *lipped* or *flushed* in at the front and top.

No broken Bricks to be used.—In order to prevent bats being purposely built in as false headers, no broken bricks, except as closers, should, strictly speaking, be allowed in the wall; as, however, it is impossible to prevent some bricks being broken in laying, specifications sometimes state that not more than a limited number, as for instance, one out of every six consecutive headers will be allowed to be broken. Such clauses are, however, better omitted, and any deviation from the letter of the specification left to the discretion of the superintending officer.

Larrying.—The best way of laying the *paving* or bricks in the body of a wall, after sufficient facing bricks have been laid, is to lay in between the face bricks a thick bed of *larry*, or rather liquid mortar, and then slide each brick along in it into its place; in doing which the mortar rises to the top of the joints, the process being called *larrying.*

Bricks to be wetted.—In order to insure the adhesion of the mortar to the bricks, they should be wetted before being built into the wall; otherwise, from their absorbent nature, the mortar will be robbed of the moisture necessary to its proper setting; in addition to which, being frequently covered with dry brick-dust, and their pores being full of air, the mortar will not adhere to them; whereas, if wet, the dust will become incorporated with the mortar, which, as the water evaporates from the bricks, will enter their pores, and insure an intimate union. A small tank may often have to be formed on the site of the work to hold water for this purpose.

To wet the bricks, before taking them on to the scaffold, greatly increases their weight, and hence the labour of carrying them, whilst in hot weather they would probably dry before being used; therefore a better plan—and one which in building in cement is absolutely necessary to insure its adhering to the bricks at all—is to have a bucket of water with a brush in it on the scaffold, into which the bricklayer may dip the bricks, and each course should be sprinkled with the brush, or through the rose of a watering can, before laying a fresh one.

Sand on Bricks.—Some bricks, such as the ordinary London stocks, are often so covered with the sand, used to keep the clay from sticking to the mould, that even cement will take no sure hold on them unless the sand is removed; this may be done by turning a hose on to them and so washing it off.

Cement Mortar to be Fresh.—In laying bricks in cement small quantities only should be mixed at a time, and no chopping up the cement with the trowel, and using it after it has once begun to set, should be permitted.

Laying face Bricks.—In walls required to be jointed on both faces a man should be employed on each side of the wall, as one man cannot work both faces properly; and in no case should a man be allowed to lay face bricks either standing on the opposite side of or on a wall.

Protecting Cement Work.—In thick walls, such as retaining and dock walls, when built in cement, if the bricklayers have to stand on them to lay the *paving* or bricks in the body of the wall, the specification should bind them to lay boards over the green work, so as to guard against disturbing the bricks by treading on them before the cement has set hard; for if the adhesion is once destroyed it can never be renewed. The quicker the cement is in setting the more care should be taken.

Grouting.—To guard against the joints in the heart of the wall not being filled up solid with mortar, *grouting* is often resorted to, especially in thick walls and foundations. This consists of pouring over each course, or over every third or fourth course, liquid mortar or cement, called *grout,* to run in and fill up all interstices. It is frequently only a remedy for bad work, but as it is next to impossible to get the joints filled in solid, and the bricks properly wetted in dry weather, it is often advisable to use it.

Grout is much used in setting large stones, as in no other way can the vertical joints be filled in solid. Cement grout is also run into the vertical joints of brick walls to render them damp-proof, see p. 57.

Joints of Brickwork.

Thickness of Joints.—Mortar being not only used to cement the bricks together, but also to form a yielding bed which will accommodate itself to any irregularities in their shape, and so reduce the risk of their fracturing under heavy loads, it follows that the more misshapen the bricks are, and the coarser the mortar, the thicker the bed-joints must be, and *vice versâ.*

In good work the joints should not exceed $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in thickness, but the thinner the bedding joints are, the more carefully must the materials composing the mortar be ground, or *screened*, to get rid of any hard substances, such as pebbles, which would tend to fracture the bricks, by concentrating, instead of distributing, the pressures.

As already remarked, the bed-joints should not be made thinner on the face than in the body of the wall, nor should a quick setting mortar or cement be used to the facework, and a slow setting and therefore more compressible mortar in the interior, otherwise unequal settlement may ruin the work.

It is customary to specify that no four courses shall *gauge* over 11 to 12 inches in height; much depending on the thickness of the bricks used, which will vary from $2\frac{1}{4}$ to $2\frac{3}{4}$ inches. A better plan is to specify that no four courses, including three joints, shall gauge more than a given amount, say 1 inch, in addition to the thickness of the bricks themselves.

Thick joints, not to speak of their appearance, yield more under pressure, leading often to unequal settlement and cracks; moreover, in yielding, the mortar is squeezed out, and projects beyond the face of the work (as at *k*, Fig. 25, only with a rougher edge), catching the rain and snow, and so allowing wet to find its way in, which, if frost follows, will expand in freezing, causing the mortar, directly a thaw sets in, to fall out and crumble away.

Jointing.—The joints of brickwork are finished either by *jointing* or *pointing*. In *jointing*, the rough joints, as left after bedding the facing bricks, are merely trimmed up in one of the following ways:—

Flat joint, or *flat flush joint*, in which the mortar is pressed flat and flush with the face of the wall, as at *a*, Fig. 25, without any trimming or cutting.

Flat joint and *jointed*, similar to the last, except in being *jointed* or marked all along the centre with an indent, as at *b*, made with the *jointer*—an S-shaped piece of iron—run along a wooden straight edge, called a *jointing rule*, 8 to 10 feet long and about 4 inches broad. In the absence of a jointer, anything to hand may be used instead, such as the edge of the trowel or the bow of a key.

Struck joint, in which the point of the trowel is drawn along the joint, neatly cutting it along one edge and slightly pressing or *striking* back the mortar along the other edge, which should be the top edge in the bed-joints, as at *c*, in order to throw off the

rain; though the lower edge is the one which—except in *overhand* work, or striking the joints by leaning over from the opposite side of the wall—is always struck back, as at *d*, thus forming a ledge to catch the rain and direct it into the joints. This is an important point to attend to, and one which, when neglected, leads to endless expense in the shape of periodical *raking* and *pointing*; for when wet gets into the joints—which it will through the finest cracks caused by the shrinking of the mortar in hardening—a frost will soon destroy them, as described above, and necessitate their being *raked* and *pointed*.

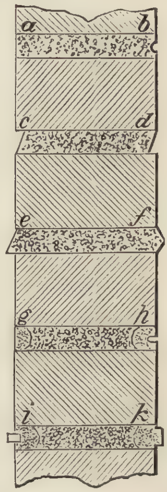


Fig. 25.

Mason's joint shown at *e*, in which the bed-joints are struck back along the upper edge, and the lower edge is cut with the trowel, and left overhanging. No better joint than this can be used for throwing off the rain. The mason's V-joint is shown at *f*.

Keying for Plaster.—When the brickwork is to be faced with plaster the joints are either left with the mortar projecting, to form a key, as at *l*, Fig. 26; or, if the mortar would not set hard enough for such treatment, a key is formed by raking the joints, as at *m*.

Pointing.—In addition to the different methods of *jointing* just described, a system of *pointing*, shown at *g*, *h*, *i*, *k*, Fig. 25, and ignorantly regarded as more suitable to superior work, is much employed. It ought never to be allowed, except in renewing perished mortar on the face of old brickwork, or where the bricks are laid in mortar which would not stand the weather, or in making good the joints of brickwork laid in frosty weather, when it would be useless to attempt to finish them off as the work went on; in such cases the pointing should be finished as at *a*, *b*, *c* or *e*, Fig. 25, viz., as a *flat joint*, a *flat joint jointed*, or a *mason's joint*, and no fancy projecting pointing should on any account be allowed.

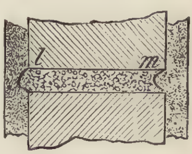


Fig. 26.

In *pointing* the joints are raked out with a *raker*—a piece of iron with both ends pointed, and bent in opposite directions—and then filled in with cement or mortar *stopping*, as at *g*, *h*, *i*, *k*, Fig. 25, by means of *pointing tools*, which are small special trowels.

Either cement or good hydraulic mortar should be used in pointing, mixed with at least twice its bulk of sand, to prevent shrinking, and getting loose in the joints; and the joints should be raked to a depth of at least $\frac{3}{4}$ inch, brushed clean with a hand-brush, and well wetted just before putting in the stopping.

The fancy systems of pointing most in vogue amongst bricklayers, who naturally look to the periodical raking and repointing in store for them, are *tuck* and *bastard-tuck* pointing.

Tuck pointing, shown at *i,* Fig. 25, consists of filling up the raked joints, flush with the face of the work, with *stopping,* which is generally coloured, or rubbed over with a piece of soft brick till the bricks and joints are the same colour. A small groove is then, or ought to be, formed along the centre of the joint, as in jointing, and the mortar is allowed to set a little. Then for white tuck pointing, *white lime putty,* made of pure lime slaked in a quantity of water, and strained off while hot—the water being allowed to evaporate till it is about the consistency of cream—is afterwards mixed with about 3 of fine washed silver sand, or better, of white marble dust, and worked into the groove with a *flat jointer* run along a straight edge, so as to form a raised line, the sides of which, whilst still soft, are *drawn* or cut perfectly parallel by drawing the *pointing knife* (called in the trade a *frenchman*), along the straight edge; the knife trims both edges, and scrapes off the superfluous putty, leaving a raised white line standing out on the centre of the joint from $\frac{1}{4}$ to $\frac{1}{8}$ inch broad.

When the stopping and bricks have been carefully brought to one colour, this thin white line gives the appearance of large perfectly shaped bricks laid with very thin joints, and is therefore very effective in disguising cheap and bad work, besides catching the rain and directing it into the joints.

Coloured lime putty is sometimes used in tuck pointing instead of white, chiefly with white bricks; it is made in the same way, but coloured with lamp or vegetable black for black putty, and with Spanish brown or Venetian red for red putty. Sometimes about a quart of linseed oil or glue size is added, per bushel of unslaked lime, to make the putty work and bind better.

Coloured stopping, made to match the bricks, generally consists of one gray lime to three fine washed sand, brought to the required tint with yellow ochre for yellow bricks, about 2 lbs. to each hodful of stopping, and with Spanish brown or Venetian red and a little vegetable black for red bricks.

Bastard-tuck or *half-tuck pointing*, shown at *k*, Fig. 25, has no white or coloured line tucked into the stopping of the joint, but a flat projecting ridge of the stopping itself, from $\frac{1}{4}$ to $\frac{3}{8}$ inch broad, is formed with a *jointer* and straight edge of the required breadth, and carefully *drawn* on both edges with the *frenchman* as in *tuck pointing*. It is a good joint for the bricklayer, since the more it projects the sooner will he be called upon to rake and point it again.

Coloured pointing mortar.—For *blue pointing*, sifted cupola, or forge coal, ashes are used in place of sand; and as they improve the setting properties of the lime, stone, and even chalk, lime is used. Other colours are obtained by adding ochres and lampblack, which, however, injure the mortar. For *black pointing* about 6 lbs. of lampblack are added to a bushel of mortar; but the best black stain is "green charge," a cheap moist refuse from gunpowder factories, which greatly improves the mortar. Black foundry sand and forge scales or blowers are also used, the latter increasing the setting and hardening properties of the mortar.

Colouring washes are used to give a superior and more uniform appearance to new, as well as in furbishing up old, brickwork.

The wall is rubbed over with bricks of the same colour, then brushed clean with a hard broom, and afterwards well wetted and washed over with the colour, generally two coats, especially with old work, the second applied after the first is quite dry. *For yellow bricks* 1 lb. of green copperas to about 5 gallons of water, according to the tint required, is generally used, and will cover about 500 feet super, depending on the bricks and the weather. *For red bricks* the wash may be made with 1 lb. Venetian red and 1 lb. Spanish brown to about $1\frac{1}{2}$ gallons of water, varying with the required tint, with about $\frac{1}{2}$ lb. of alum or white copperas dissolved in hot water, or $\frac{1}{4}$ gallon of stale beer added to fix it.

In tuck pointing red bricks one wash may be applied before, and a lighter one after, the joints have been stopped; but with yellow bricks any copperas wash applied after the stopping would whiten the joints. The wash should be mixed in one lot, and, if kept, should be weakened before again applying, to insure a uniform tint. In testing the wash for the right tint it must be tried on the same bricks, and exposed to the same aspect to dry, as the wall to be coloured, or the result will not be satisfactory.

White bricks are generally only rubbed down before stopping, but if they vary in colour the white dust may be fixed on the face by a wash of 1 lb. alum to 3 gallons hot water, applied warm.

Gauged Brickwork.

Bricks cut and rubbed to particular shapes, and to secure closely fitting joints, are used in the ornamental parts, or *dressings*, of brickwork, as in cornices, quoins, arches, etc. Such work often has an appearance of superiority which it does not in reality possess, as the *red rubbers* and *malm cutters* used for the purpose are often soft perishable bricks, chosen on account of the ease with which they can be cut and rubbed; the best rubbers, however, harden considerably with age and exposure to the weather, so much so that they have to be carefully protected from rain, and not kept too long in stock, before being cut and rubbed or carved to the required form.

When used in arches the bricks are frequently rubbed to a full width on face, and slack behind, so as to show close joints on face; a practice which leads to chipped arrises and falling arches.

In straight arches sham horizontal joints are often marked on the face to save the trouble of splaying the inner ends of the bricks, but the true joints are sure to show up in time and proclaim the fraud.

To produce the fine joints aimed at in gauge-work the bricks are generally set in lime putty made as described under "tuck pointing;" this is placed in an oblong wooden box, into which the setter dips the bed of the brick.

Rubbed and gauged work is usually measured in with the rest of the brickwork, and afterwards the superficial content taken out, and charged extra for, to cover the additional labour involved.

Tools for Cutting and Rubbing Bricks.—The following articles are used in the preparation of gauged and moulded work, viz.:—

A *banker* or wooden bench, from 6 to 12 feet long, 2 feet 6 inches to 3 feet wide, and about 2 feet 8 inches high.

Moulds for forming the faces and backs of bricks to be used as voussoirs of arches, so as to bring them to their proper taper, or for working mouldings. They are generally made of sheet-zinc cut to the required profile with shears and files.

Templets, or patterns, used for taking the exact length of the stretchers, and the breadth of the headers.

Square and bevel, with a shifting *stock*, as well as *bevels* formed by nailing together two straight edges, for working to any required angle.

Scribe, a spike or large nail with a sharp point, to mark the

brick by drawing it along the edges of the mould, etc., previous to cutting.

Tin saw, used to cut the bricks, as marked by the scribe, about $\frac{1}{8}$-inch deep, to take the edge of the brick axe.

Brick axe, for axing the bricks into shape, which is done as accurately as possible to save subsequent labour of rubbing.

Chopping block, for axing the bricks on, made of any wood to hand, from 6 to 8 inches square, and generally raised to a height of about 2 feet 3 inches, on a 14-inch brick pier.

Rubbing stone, for rubbing the bricks on. It should be perfectly level on face, and is circular, not exceeding about 14 inches diameter, or it would wear unevenly. It is fixed at one end of the banker in mortar, and should be frequently turned round to insure even wear.

Bedding stone, which is a flat piece of marble 18 to 20 inches long, and from 8 to 10 inches wide, used to prove the flat surfaces of rubbed bricks.

Float stone, for rubbing curved work smooth, made to the reverse of the intended finished surfaces, viz., convex for rubbing a concave surface, and *vice versâ*.

Damp-proof Brick Walls.

Damp-proof Coatings.—Painting, tarring, or waterproof washes (see p. 286), as applied to finished wall-surfaces, will not be dealt with here, as they in no way affect their construction.

Walls to be coated with asphalt, lime, or cement mortar (one Portland cement two sand, properly applied, is quite waterproof) are finished more or less rough on face, the joints being treated as on Fig. 26; raked joints give the best hold and are always used for asphalt. A facing of non-absorbent bricks or stone, such as polled flints (flints cut across so as to expose a smooth face), set in cement or good hydraulic mortar, may be sufficient in some cases. Sometimes brick walls are faced with glazed bricks or tiles, or, where appearance is no object, with slates to keep out the weather.

Damp Courses.—In order to keep damp from soaking up into the walls of buildings from the foundations, a horizontal damp-proof course, below the level of the lowest floor, or of the plates supporting it (Fig. 24) should cut off the footings, etc., in contact with the ground, from the wall above. It should be a

least 6 inches above the highest level of the soil touching any part of the outer walls, and should run unbroken all round them, and at least 2 feet into all the cross-walls; but on a damp site it should be continuous through all the walls, and in some cases a damp-proof layer may be required over the entire area of the building.

In buildings finished at the top with parapets, in place of overhanging eaves, it is often necessary to insert a damp course just below the parapet and above the top ceiling level, to prevent the downward penetration of damp.

Damp courses are formed of various materials, such as :—

Sheet-lead, which is efficient but costly.

Glazed stoneware perforated slabs, generally made in thicknesses of 1, $1\frac{1}{2}$, and $2\frac{3}{4}$ inches, and in 9-inch lengths by $4\frac{1}{2}$, 9, $13\frac{1}{2}$, and 18 inches in width, to suit the ordinary thicknesses of brick walls. They should be laid with the vertical joints open, as any mortar in the joints would allow of damp soaking up; some are grooved and tongued at the edges. Glazed stoneware is unrivalled as a combined damp-proof and ventilating course, its application is shown in Fig. 27.

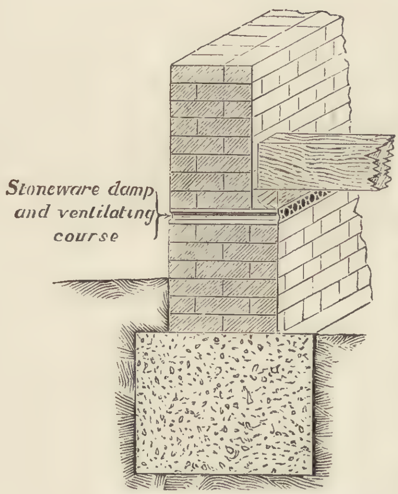


Fig. 27.

Asphalt. — For War Department buildings a $\frac{3}{8}$-inch layer of fine gritted Seyssel Asphalt is generally specified, but many other and less costly asphalts are used for the purpose.

The surface to receive the melted asphalt should be quite dry, and should be made smooth so as to economise the materials; hence, bricks with frogs should be laid with their flat sides uppermost, and all the joints should be well flushed up with mortar.

Hygeian rock, made by William White of Abergavenny, is laid like asphalt, $\frac{1}{2}$-inch thick, and at about half the cost of Seyssel Asphalt.

Artificial asphalts are sometimes used, but they generally turn

out either too soft or too brittle. They are mostly made by boiling together coal-tar and pitch, with sand and powdered chalk or slaked lime.

Roofing slates, or even *hard vitrified bricks,* two courses breaking joint, laid in half cement half sand; or a single course of such bricks laid dry, without any mortar in the vertical joints, form a good and inexpensive damp course.

Portland cement, a $\frac{1}{2}$-inch layer of half cement half sand, will often answer the purpose of a damp-proof course.

Sheet bitumen, tarred felt, and even *Willesden waterproof paper* (see p. 316), form cheap damp courses, suitable for temporary buildings, and can be supplied in rolls of the required width and laid with great facility.

Vertical Damp-Proof Courses.—*Hygeian rock composition,* referred to above, is melted and poured, at every third or fourth course, into a vertical longitudinal joint left open about $\frac{3}{4}$ of an inch; and partially running into the bed and side joints, which are left a little void for the purpose, sets hard at once, greatly strengthening the wall and making it perfectly waterproof. Roughly speaking, the reduction of half a brick in the thickness of the wall pays for the composition, and it is claimed that a 9-inch wall so constructed costs less, and has a greater transverse strength, than an 18-inch wall built in mortar, and is more impervious to heat, cold, and sound.

Fig. 28, representing an enclosed tank, proof against acids as well as water, shows the method of applying the material under different conditions, such as in walling, arching, floors, or entire basements in water-logged ground. Fig. 29 shows a waterproof stone wall lined inside with brick on edge.

Portland cement filling.—Strong and perfectly weather-proof brick walls may be built with a $\frac{5}{8}$-inch cavity, filled in with cement grout, between the outer $4\frac{1}{2}$-inch skin and the inner part of the wall, the face showing either Flemish bond, or 3 stretchers to 1 header in each course, or 2 courses of stretcher to 1 of Flemish bond. The cavity must be well flushed up solid every second course with cement grout, 1 cement to 3 washed sand. The joints of the face and back of wall must be filled up solid with mortar to within about $1\frac{1}{2}$ inches of the cavity, to retain the grout while allowing it to run into the voids to tie the face and back of the wall solidly together.

Hollow Walls.—Walls with an air space or cavity in them

are widely used to keep out damp as well as to assist in maintaining an equable temperature within the thin shells of our modern economical buildings.

As the cavity must run down in one continuous vertical line, it practically splits the wall into two thicknesses, which are tied together by damp-proof bonding bricks or iron ties, so shaped as to preclude the possibility of water running along them to the inner wall. The cavity being a source of weakness, it is necessary

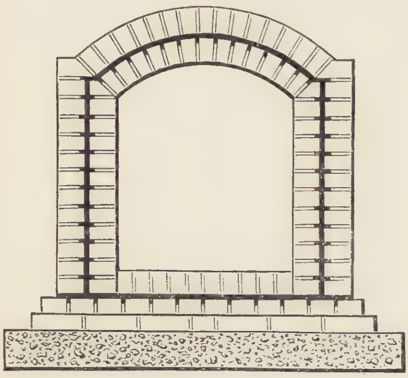


Fig. 28.

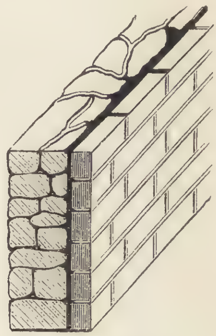


Fig. 29.

to keep the weight-carrying part of the wall as solid as possible; hence it is placed, as a rule, next to either the outer or inner $4\frac{1}{2}$-inch facing, which should, in any wall more than two half-bricks thick, be merely regarded as an extra skin, adding nothing to its weight-carrying strength.

In War Department buildings the cavity, $2\frac{1}{2}$ to 3 inches wide, is in brick buildings placed next to the outer face of the wall, in which position it keeps the weight-carrying portion of the wall dry, and is better as regards equability of temperature within; on the other hand there is the difficulty with deep reveals of preventing the penetration of damp, whilst the outer face must either show stretcher bond, or else bats must be used to represent the headers of English or Flemish bond.

Placing the cavity next the inner face, which has to be done with a brick-lined stone wall, either throws the weight of the floors upon the detached skin, or else the bearers must run into the outer damp portion of the wall.

The cavity must be carried right round all the angles and up to the sides of all door and window frames, over which, when the

outer face is only $4\frac{1}{2}$ inches thick, a strip of, say 5 lbs., sheet-lead, 4 inches wide and projecting about 2 inches beyond the head at each end, should be built about $1\frac{1}{2}$ inch into the outer skin, the remaining $2\frac{1}{2}$ inches projecting into the cavity, with the outer edge turned up, so as to catch any rain driving through, and running down the inside or dropping off the bonds above, and throw it clear of the sides of the frame.

The cavity should be closed at the top, more especially if it is next the inner face, as equability of temperature within is more important than assisting the drying of the outer wall by the circulation of air in the cavity.

The usual practice is to carry the hollow space, or the solid damp-proof composition when used, down to the horizontal damp course, which is carried right through the wall.

When the cavity is only $4\frac{1}{2}$ inches from the outer face, and the

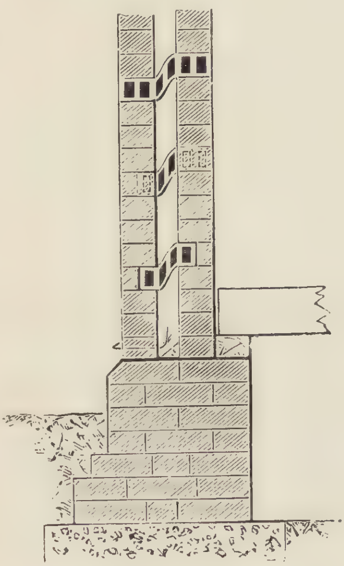


Fig. 30.

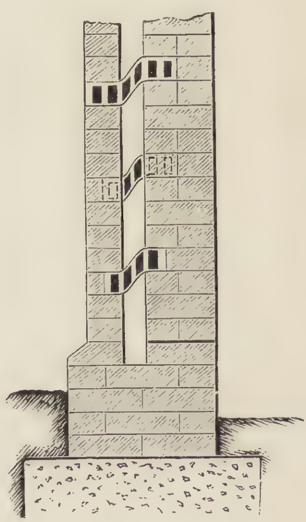


Fig. 31.

wall is exposed to heavy driving rain, the cavity should, if terminated at a damp course without any open joints, be provided with outlets for the escape of any water running down inside, and a cement or asphalt fillet should, as in Fig. 30, throw any water away from the inner wall; or the cavity may be continued, as in Fig. 31, a little below the damp course, which need only run

through the inner portion of the wall, provided, of course, that it is not a combined damp and ventilating course, as in Fig. 27.

In building hollow walls great care should be taken to prevent mortar dropping into the cavity and lodging on the bonds, or damp will soak through the mortar to the inner wall. To guard against this, iron piping or battens, with haybands wound round them, should be placed in the cavity on the last laid bonding ties, and shifted before the next row of ties is laid.

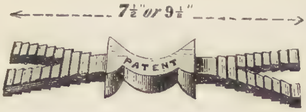
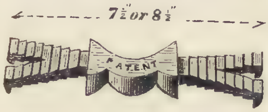
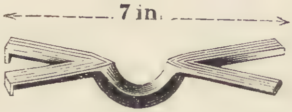
The walls of several houses at Birchington-on-Sea have been rendered perfectly impervious to the driving wind and rain by fixing slates resting on the iron ties in the cavity between an inner 4½-inch wall and an outer one of rough burrs or clinkered bricks; but it is probable that hollows in walls will eventually be, in a great measure, superseded by some such water-proof filling as the Hygeian rock referred to on page 57, which, at the same time, adds to the strength of the wall.

Bonds or Wall Ties for Hollow Walls.—These are generally either of glazed stoneware or of iron, though slate bonds are sometimes used, and the more non-absorbent bricks such as blue Staffords, and even common bricks with their inner ends dipped in boiling tar; but such cheap substitutes for special bonds are certain to let the damp through when built into an outer 4½-inch skin.

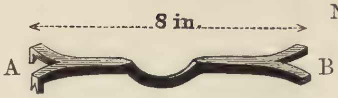
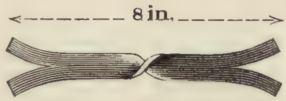
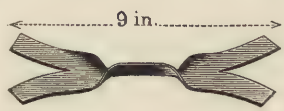
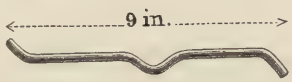
The bonds are generally placed about 3 feet apart horizontally, and from 9 (in most War Department buildings) to 18 inches vertically, giving from 8 to 4 per yard super.

Iron bonding ties of different forms, with their comparative cost and number per cwt., are given below.

CAST-IRON WALL TIES.

	No. per cwt.	Cost per cwt. s. d.
7½" or 9½" 	...	14 0
7½" or 8½" 	...	14 0
7 in. A  B	290 A 300 B	13 0

WROUGHT-IRON WALL TIES.

	No. per cwt.	Cost per cwt. s.	d.
	480 A	17	6
	500 B	19	6
	300	17	6
	230	17	6
Wire. 	600	22	6

Those with the ends turned down are only for use when the bricks have a kick or frog in them, in which the bent ends are intended to catch.

The cast-iron ties, though cheaper and less liable to rust than wrought-iron, would be more liable to snap across, therefore they are rendered malleable if desired.

They can be protected by galvanising at a cost of about 8s. per cwt., or 3s. for the wire ties. In any case they should be dipped in boiling tar, and are better sanded, to give the mortar a hold upon them. Every precaution should be taken to guard against their rusting, for in so doing they will swell and open up the joints, and may become a source of danger to the wall.

Glazed stoneware bonds are either straight, as shown on Fig. 32, or bent as on Figs. 30 and 31, the bent being the latest pattern.

Their lengths are such as to allow either a $2\frac{1}{4}$ or a $4\frac{1}{2}$ inch cavity, and a hold in the wall of $4\frac{1}{2}$ inches at each end, or of $2\frac{1}{4}$ inches at one end and $4\frac{1}{2}$ inches at the other, according as their ends may show on the face of the wall or not.

Damp-proof Basement Walls.—External walls below the ground-level may be rendered damp-proof by any impervious external coating, such as cement or asphalt, or some vertical damp-proof composition in the interior of the wall, as described on page 57, running down to the horizontal damp-course; or by

building that part of the wall with a hollow space, and arranging the damp-course as in Fig. 32.

In the case of underground cellars, etc., on very wet sites, the entire building below the highest water-level of the surrounding ground may require to be treated like an underground tank, on the principle shown in Fig. 28, page 58.

Dry Areas.—These are enclosed air spaces, sometimes misnamed "air drains," used to keep damp earth from direct contact with

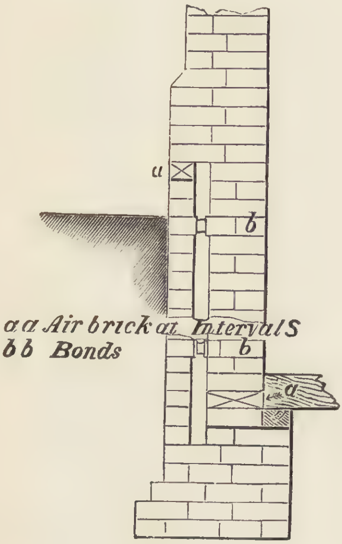


Fig. 32.

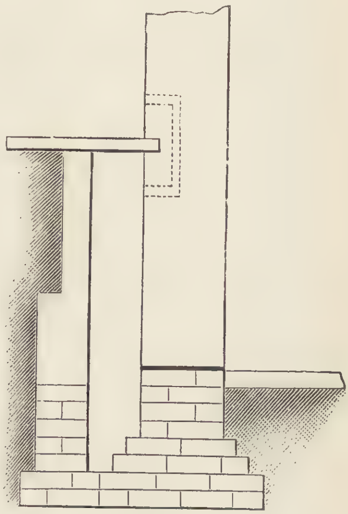


Fig. 33.

underground walls, where open areas are undesirable on account of the cost or want of space outside the wall. They may be formed by building an independent wall, just capable of supporting the earth behind it, from 9 to 18 inches clear of the building, and covering over the air space so formed, as most convenient, at the same time providing for its proper drainage and ventilation, the latter being arranged so as to prevent the entrance of any rain, as for instance in Fig. 33.

In some cases the earth is kept away from the wall by merely building up rough clinkers or dry stone packing against it; in other cases a 4½-inch brick wall is built up 4½ inches from the main wall, resisting the earth pressure by means of headers merely butting against the wall; the butting headers may be dipped in

boiling tar to check the passage of damp, or special non-absorbent bricks may be used for the purpose; and the detached skin can be carried a little way above the ground, and treated as a base or plinth course.

In localities where stone or slate slabs are abundant, a dry area formed of slabs leaning against the face of the wall, as shown in Fig. 34, will often answer the purpose.

Brick Footings, Corbelling, Coping, and Hoop-Iron Bond.

Footings to Brick Walls.—Brick footings should be built in English bond, and, if resting direct on ordinary firm ground, should be widened out to about twice the width of the wall above, by regular quarter-brick offsets, of one or more courses in height (generally two courses); the bottom offset should never be under two courses high.

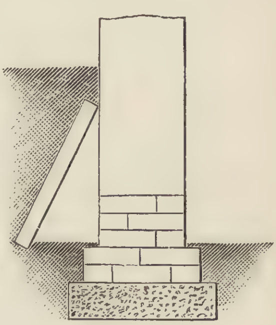


Fig. 34.

Two of the inside offsets, making together $4\frac{1}{2}$ inches, are often carried up to take the wall plates supporting the lowest floor, as shown on Figs. 27 and 30, and by dotted lines on Fig. 32.

With concrete foundations it is often better not to widen out the bottom of the wall, but to carry up the concrete to within a few inches of the outside ground level, or to the level of the ground within the building, as shown in Figs. 27 and 31; thus resting the walls on deep concrete beams, as it were, which are more likely to carry them, without settlement, over any soft spots in the foundations, than the comparatively thin layers of concrete in more ordinary use. As the width of the concrete need not exceed the necessary width of the footings, supposing there to be no concrete, there is a considerable saving over the common system of first spreading the footings, as if they stood on the ground, and then making the concrete foundations about 12 inches wider still.

Brick Corbelling.—In corbelling out brickwork, the oversail or projection of each offset should not exceed a quarter brick, or one-eighth of a brick where extra strength is required.

The total projection to carry plates for floor joists should not

be under $4\frac{1}{2}$ inches, consisting of at least two upper courses of headers only, as shown on Figs. 35 and 36.

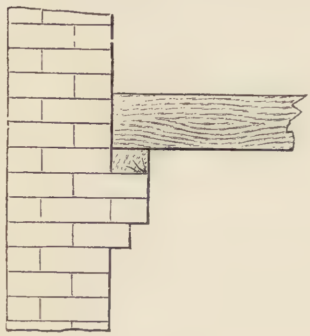


Fig. 35.

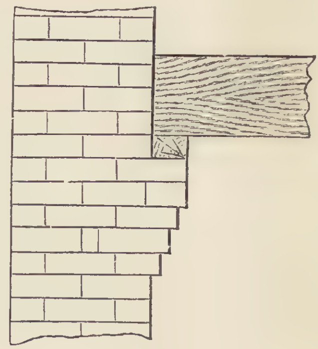


Fig. 36.

Brick Coping.—*Brick coping* for walls, whether of ordinary bricks on edge, or of special non-porous blocks moulded to shape, should be set in hydraulic lime or cement mortar. Any projection below the coping has a tendency to arrest water and encourage the growth of vegetation both above and below it.

Tile creasing consists of two or three projecting courses of plain tiles, inserted below a flush coping, they should be laid in cement mortar, breaking joint.

Hoop Iron Bond.—*Hoop-iron bond*, consisting of hoop-iron 1 to $1\frac{1}{2}$ inch wide, and 16 to 18 S.W.G. (about $\frac{1}{16}$ to $\frac{1}{20}$ inch thick; see Appendix IV.) is often built into brickwork to add to its strength; at the same time it considerably increases its cost and should never be relied on for permanent strength, though sometimes of great use as a precautionary measure during the erection of buildings on treacherous foundations.

The hoop-iron strips are laid in continuous lengths, side by side, say at every third or fourth course, the joints between the lengths, or at any angles, being made by bending or folding the ends over each other.

The number of strips in each bed-joint mostly varies from one to two per brick in thickness of the wall.

Lengths of hoop-iron bond are often built into walls, with the ends left protruding, in order to form a junction with another wall to be built later on.

In foundations below ground, in outer walls, and wherever damp is liable to penetrate, hoop-iron bond should be most care-

fully protected by being well tarred and sanded and laid in cement mortar. Sanding gives it a hold on the mortar, the edges being often jagged for the same purpose. If damp gets to the iron, and oxidation sets up, it expands with resistless force, opening up the joints of the brickwork; in the case of a high prison wall it became fully $\frac{3}{4}$-inch thick, with the result that the wall was blown over under a wind pressure which otherwise would have had no effect upon it.

Brick Arches.

Common, Plain, or Rough Arches.—These are formed of ordinary unsplayed or rectangular bricks, so that their bed-joints are V-shaped; hence they are generally built in half-brick rings, showing stretcher bond on the underside, the "intrados" or "soffit."

In quick sweep or sharp curved arches, such as arches of 4 feet radius and under, half-brick rings are necessary, as the joints at the back or "extrados" of a 9-inch ring would be too open both for appearance and strength, though the latter might be remedied by the use of cement.

Such arches are used for bridges, tunnels, and any rough work where appearance has not to be considered, as in arches over fireplaces, in trimmer or half arches to carry hearths, etc. (see Fig. 43), and in internal discharging or relieving arches over wood lintels, etc., in which case the arch should always run clear of

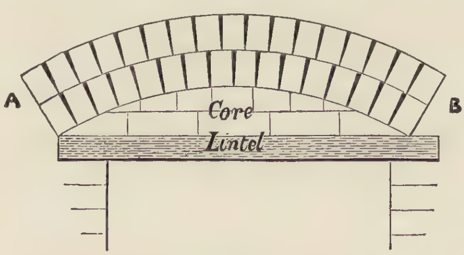


Fig. 37.

the ends of the lintel, as at A, Fig. 37, and not as at B, the "core," or space between the lintel and the arch, being filled in with bricks and bats cut to the curve and laid in mortar.

Arches of large radius are often built in English bond, showing

alternate header and stretcher courses on the soffit; the face or end elevation being as in Fig. 38.

Flemish bond is seldom used, except perhaps in arch rings 9

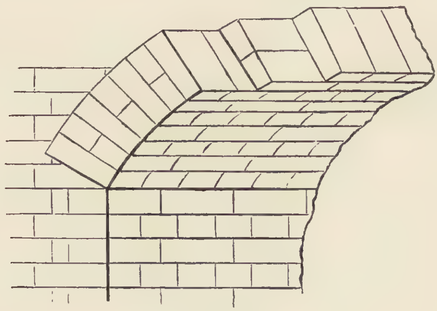


Fig. 38.

inches deep, not being so strong; moreover, the bats which would be required, in arch rings an uneven number of half-bricks in depth, would be most undesirable.

In very deep arch rings the bed-joints of the voussoirs would be too open at the extrados if bonded throughout; hence it is better in such cases to build the arch in half-brick rings, with a few bonding or lacing courses built in at intervals, to tie the separate rings together, as shown at A, Fig. 39.

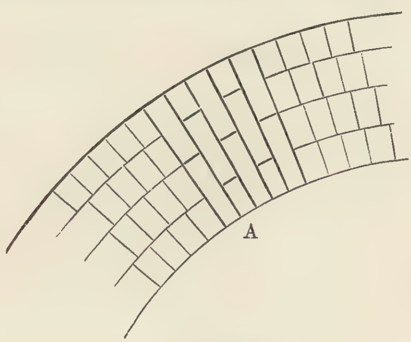


Fig. 39.

These bonding courses, which are inserted wherever the beds of the bricks in the different rings coincide, prevent the concentration of the pressure on any particular arch ring, and are particularly desirable for spans over about 30 feet.

Moderately slow setting mortar is considered preferable for

large arches, to allow of the voussoirs, when the centres are eased or struck, slightly accommodating themselves to the pressures.

Rough Cut or Axed Arches.—These are so named from the curvature being due to the bricks being roughly cut to splayed or wedge-shaped voussoirs, the bed-joints being rectangular, *i.e.* the same thickness at the extrados as at the intrados. They are used for facework of a rather better description, and for small arches set in common mortar, where strength is required.

In setting axed arches the bed-joints are often "buttered," a little mortar (sometimes Portland cement with a little lime putty added) being drawn along the edges, leaving the hollow bed to be grouted in with lime or cement grout.

Gauged Arches.—These are used for superior facework, and are built of bricks carefully rubbed and gauged to accurately shaped voussoirs. The joints are made very thin, from $\frac{1}{8}$ to $\frac{1}{16}$ inch thick, the bricks being generally set in fine lime putty, as described under "tuck pointing" on p. 52.

Plain or Ornamental Moulded Arches.—These are constructed of moulded brick voussoirs, and are chiefly confined to facework and arches requiring great strength.

Straight and Camber Arches.—Used for the outer $4\frac{1}{2}$-inch facing of straight heads to window and door and other openings. Though straight at the extrados, a slight curve is given to the soffit or intrados, to guard against sagging in case of a little settlement.

When a very perceptible rise or camber is given to the soffit they are called *camber* arches. They may either be built of ordinary or plain, axed or rough cut, rubbed and gauged, or moulded bricks.

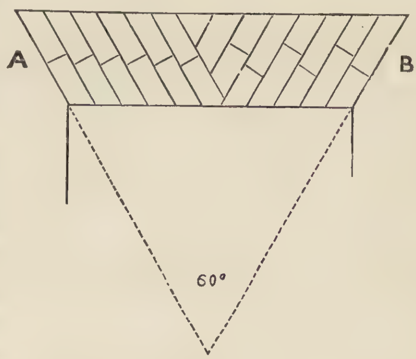


Fig. 40.

Plain Straight Arches (Fig. 40).—They are also called *French* or *Dutch arches,* and are sometimes used by builders when intended to be plastered over or otherwise hidden from view. They are unreliable unless built in good hydraulic or cement mortar. The joints may be arranged as at A or at B; if, as at A, only whole bricks could be used.

Gauged Straight Arches (Fig. 41).—These are in very common use, and are generally 12 inches, or four courses of brickwork, in depth.

The *sommering* or splay of the bricks depends upon the angle given to the skewbacks or springings, and varies with the distance of each voussoir from the springing.

The skewbacks are generally inclined at 60° from the horizontal, and are struck by prolonging the sides of an equilateral triangle, as shown on Fig. 40.

The joints give a better appearance when horizontal, as at B,

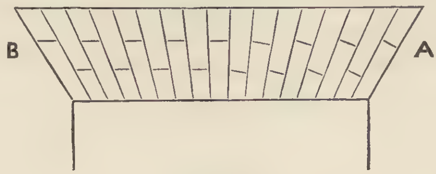


Fig. 41.

Fig. 41; but to save labour they are frequently formed as at A, and carefully concealed by rubbing over, false horizontal joints being marked on the face, though in course of time the true joints are sure to show up and expose the sham.

Axed Straight Arches.—These are seldom used. Their appearance is similar to the gauged straight arch, Fig. 41, the joints being coarser and more likely to be formed as at A than as at B.

Brick Chimneys and Flues.

Chimneys.—Fig. 42 shows how ordinary smoke flues are gathered or contracted at the throat, bent to check any direct down draught, or rain, finding its way down, and turned over to their positions in the chimney breast.

The outer walls in good work should be one brick thick instead of only half a brick as shown.

Fig. 42 also shows the junction of a chimney breast with the shaft passing through the roof, from just above the highest ceiling level. The horizontal projections of the steps or offsets, where the flues are gathered over, should not exceed one-sixth of a brick, especially in the half-brick *withs*, as the partitions between the flues are termed.

The oversailing or overhanging angles of the bricks, shown by

dotted lines, are cut away to remove any obstacle to the ascending smoke; whilst the re-entering angles, in the receding brickwork, should be filled up with mortar.

Fig. 43 gives a vertical cross-section of an ordinary fireplace

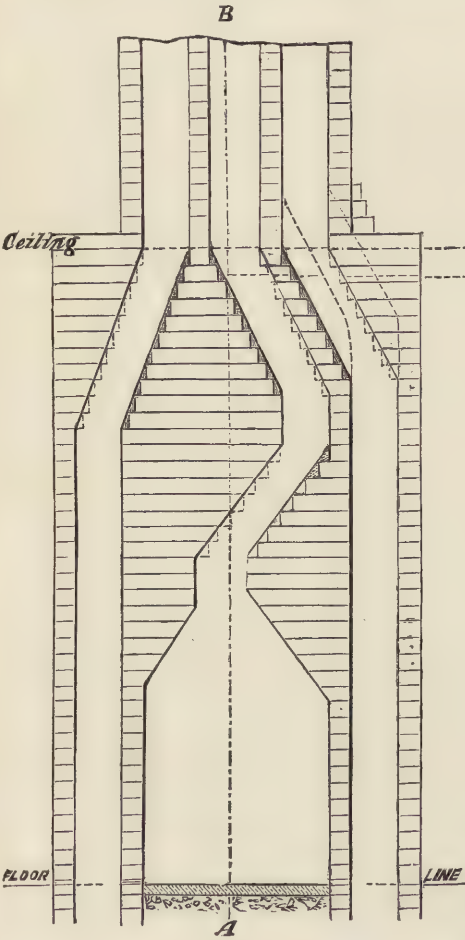


Fig. 42.

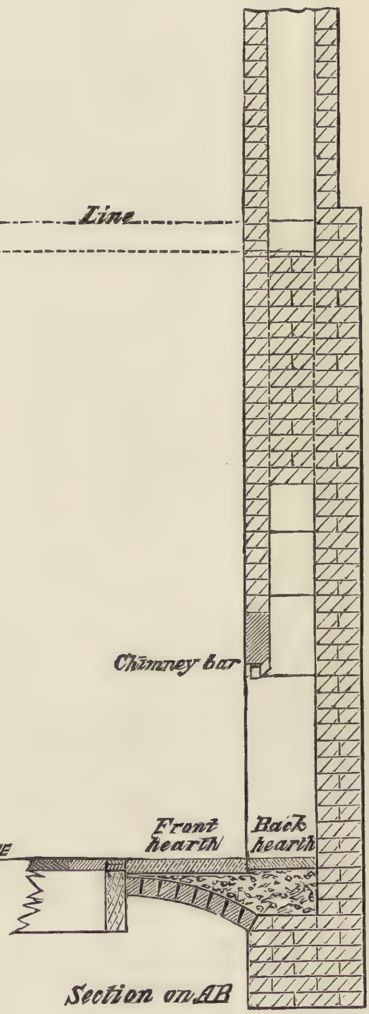


Fig. 43.

on an upper floor, showing a brick trimmer arch carrying the hearth-stones. Concrete is shown under the back hearth, in place of the ordinary brick filling. The stone-hearths might be dispensed with, and the surface finished with an inch of half Portland cement half sand; and even the

trimmer arch is often omitted, and a solid slab of Portland cement concrete built into and projecting from the wall.

Figs. 44-47 are horizontal sections, showing different methods of bonding the bricks in chimney-stacks. Fig. 44 shows two consecutive courses in English bond with a 9-inch outer shell, which is much better than the cheaper but almost universal $4\frac{1}{2}$-inch work. A foul-air flue is shown in its best position between two smoke flues. Fig. 45 shows the common $4\frac{1}{2}$-inch chimney or stretcher bond, and Figs. 46 and 47 the same in Flemish bond,

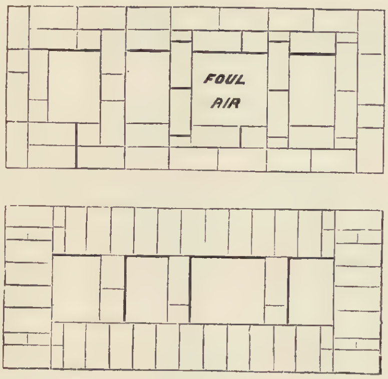


Fig. 44.

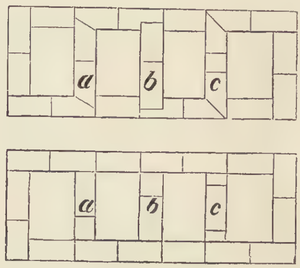


Fig. 45.

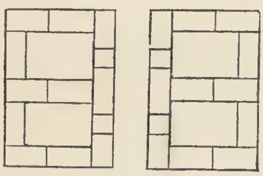


Fig. 47.

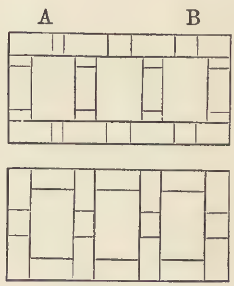


Fig. 46.

which, especially Fig. 47, works in very simply. A and B in Fig. 46, and *a*, *b*, *c* in Fig. 45, show different methods of working the same bond.

As chimney-stacks admit of endless variety as regards the number, size, and arrangement of the flues, both for smoke and ventilation, the strength of the work and the satisfactory drawing of the flues, depends greatly on the skill of the bricklayers employed upon them; hence, they should only be entrusted to good workmen. Good mortar should be used throughout, and the bricks in the chimney-caps should be laid in cement mortar,

to guard against the damage and danger arising from any bricks getting loose and falling, not to speak of the trouble and expense of repairing them.

Flues.—Smoke flues are generally made 14 by 9 inches, or $1\frac{1}{2}$ brick by 1 brick, though 9 by 9 inches is quite large enough for the flues of ordinary domestic fireplaces, kitchens excepted. In former days the larger size was necessary, as the flues were swept by boys climbing up them.

Pargeting flues is rendering their insides smooth, retentive of heat, and proof against cold air entering them through the joints and pores of the thin brickwork, or smoke finding its way to the bricks and discolouring the wall surface of the rooms. The *parge* or plaster should consist of 1 lime to about 3 of dry cow-dung, which renders it fibrous and tough enough to stand the alternate heating and cooling without dropping off.

Portland cement mortar may be used for the same purpose, for, if properly done, it adheres firmly to the sides of the flues.

Coring Flues.—*Coring flues* is passing a wire brush or other core through them, after completion, to see that they are clear.

During construction they should be stopped by drawing up inside them, as they run up, a *sweep* or bundle of rag or hay, so as to intercept any bricks or mortar which might otherwise fall down and lodge in the bends.

Brick Nog Partitions.—*Brick-nogging* is a term applied to thin walls or partitions, with wood framing filled in solid with bricks, and generally consists of vertical timber studs or quarterings, about 4 by 2 inches, framed, at about six-brick intervals, into 4 by 3 inch top and bottom sills, and filled in with bricks laid stretcherwise, with horizontal nogging pieces, about 4 by $\frac{3}{4}$ inches to 1 inch, inserted at about every four or more courses in height.

Very thin brick-nog partitions are formed by placing the bricks on edge instead of on the flat.

Sundries Connected with Bricklayer's Work.

The other descriptions of work performed by the bricklayer, and enumerated in the War Department Schedules, mostly require no special explanation. The way in which they are charged is given against each separate item. The cost of materials required for use or store, as well as the price of *labour only*—subject to a

percentage to be taken off or added on, according to the terms of the contract,—are given at the end of the Schedule of Contract for each particular trade.

For the *weight, absorption,* and *strength* of bricks, brickwork, and tiles, see *R. E. Aide Mémoire,* par. 900; Rivington's *Building Construction,* part iii., pp. 112-116; also Hurst's *Handbook, etc.*

The thickness of walls of dwelling-houses, warehouses, etc., as required by the Metropolitan Building Act, are given in the *R. E. Aide Mémoire,* pars. 112-115; also Hurst's and Molesworth's *Handbooks, etc.*

Valuation of Brickwork.

It is customary to express the dimensions of brickwork in terms of the length of the brick employed. Thus in London a half-brick wall implies a thickness of $4\frac{1}{2}$ inches; a two-brick wall a thickness of 18 inches, and so on.

Measuring by the rod.—Ordinary brickwork is measured by the *rod* or square perch, at a standard thickness of $1\frac{1}{2}$ brick.

A rod is therefore $16\frac{1}{2}$ by $16\frac{1}{2}$ feet, or $272\frac{1}{4}$ feet super; therefore a rod of brickwork, $1\frac{1}{2}$ brick or $13\frac{1}{2}$ inches thick, contains 306 cubic feet or $11\frac{1}{3}$ cubic yards.

To reduce brickwork of any thickness to rods, multiply the superficial content of the wall by the number of half bricks in its thickness, and divide the result by 3, which will give the number of feet super at the standard thickness of $1\frac{1}{2}$ brick; then divide by 272—the number of feet super in a rod, less the quarter foot, which is neglected—this will give the number of rods of *reduced* brickwork, or brickwork reduced to the standard thickness of $1\frac{1}{2}$ brick.

Reducing cubic feet to rods.—Sometimes brickwork has to be measured up in cubic feet, and reduced afterwards to rods; to do which multiply by 8 (the number of $1\frac{1}{2}$ inches in 1 foot), and divide by 9 (the number of $1\frac{1}{2}$ inches in $1\frac{1}{2}$ brick, or $13\frac{1}{2}$ inches); or, which is the same thing, deduct one-ninth; this will give the number of feet super of reduced brickwork, which must be divided by 272 to arrive at the number of rods.

Measuring by the yard and square.—On large engineering works brickwork is generally paid for by the cubic yard, but some such system as the London practice of measuring by the rod, at a

standard thickness of bricks, is, for ordinary purposes, to be preferred, as it affords no incentive to the bricklayer to try and add to the cubic content of the brickwork by using wide and open joints in the interior of his wall, where they could not easily be detected.

In some counties brickwork is measured by the yard super, at a standard thickness of 1½ brick; the square of 100 feet super would, however, be by far the best mode of measuring; for the feet super, at 1½ brick thick, would be reduced to squares by merely pointing off the last two figures, whilst it would be a large enough unit to allow of a moderate alteration in price.

Estimating Materials.—In estimating the number of bricks required for a given amount of brickwork in mortar, supposing the bricks to have been turned out of a mould 9 × 4½ × 3 inches, the following will give a fair allowance, including waste:—

15	bricks	per cubic	foot.
390	„	„	yard.
4400	„	per rod.	
7	facing bricks per foot super.		

For further information as to the materials required, as in brick-nogging, paving, tiling, etc., as well as of the amount of sand, lime, cement or mortar, necessary for different purposes, refer to Hurst's *Architectural Surveyor's Handbook.*

Cost of Brickwork.—The prices allowed for brickwork vary greatly, according to the description of work required; they include all necessary scaffolding, but not wood centering to arches, which is provided by the carpenter.

The method of getting at the cost of brickwork is as follows:—

DETAIL OF A ROD OF BRICKWORK IN 1 LIME, 2 SAND.

		£	*s.*	*d.*
4400	gray stocks at 35s. per 1000 . .	7	14	0
1½	yard or load, or 32 bushels, stone lime at 10s.	0	15	0
3	yards or loads, or 64 bushels, sand at 4s. .	0	12	0
4	days, bricklayer and labourer at 9s. .	1	16	0
2	days, labourer, mixing mortar at 3s. .	0	6	0
126	gallons, water, cost varies from . .	0	0	0
Use of scaffolding, erecting, striking and carting .		0	3	0
	Total (with 10 per cent profit) . .	£11	6	0

DETAIL OF A ROD OF BRICKWORK IN 1 CEMENT, 2 SAND.

		£	s.	d.
4400	gray stocks at 35s. per 1000	7	14	0
27	bushels, Portland cement at 2s. 6d.	3	7	6
$2\frac{1}{2}$	yards or 54 bushels, sand at 4s. 6d.	0	10	0
$2\frac{1}{2}$	yards, washing ditto at 1s. 6d.	0	3	9
6	days, bricklayer and labourer at 9s.	2	14	0
Water, scaffolding, etc.		0	3	0
	Total (with 10 per cent profit)	£14	12	3

DETAIL OF A YARD OF BRICKWORK IN 1 LIME, 2 SAND.

		s.	d.
390	gray stocks at 35s. per 1000	10	8
$\frac{1}{8}$	yard, stone lime at 10s.	1	3
$\frac{1}{4}$	,, sand at 4s.	1	0
Labour, etc.		3	6
	Total (with 10 per cent profit)	16	5

The time allowed for in the above details only includes rough brickwork, the jointing must be taken in addition, by the foot super.

If superior facing bricks are used, the extra cost of such bricks must be taken, reckoning seven bricks to every foot super of facing, and deducting the number of facing bricks from the 4400 bricks required for a rod of brickwork, and extra time must be allowed for the facing. Extra time must also be allowed for jointing, at the rate of about one day for each superficial rod.

Sometimes different prices are allowed for brickwork in foundations and over foundations; in the latter case including joints and picked facing bricks. The best plan, however, is that of charging the extra work to jointing and facing, at so much per foot super, in addition to the cost of the rough brickwork.

Curved brickwork is commonly described as *flat sweep* when over 25 feet, and *quick sweep* when under 25 feet, radius; the extra labour being paid for by the foot super. In *very quick sweep* work, however, a higher price must be allowed for the solid content, on account of the cutting required throughout the thickness of the wall. From 8s. to 12s. a rod is the extra cost of the labour on curved work, as a rule.

Chimneys, with flues under an area of 2 feet, coppers, and ovens, are measured solid—openings to fireplaces, ash holes, and $\frac{3}{4}$ the cubic content of boilers, being deducted. This is to cover the

extra trouble in forming and *pargeting* the flues. The bricklayer should be bound by his specification to *core* or clear the flues.

Arches, cornices, etc., are measured up as ordinary brickwork, and then an extra amount per foot super allowed, according to the nature of the work.

Raking out and *pointing* to the soffits of arches and vaults, when required to be finished fair, is always paid for separately, by the foot super., as it has to be done after the centering is removed.

Brick-nogging is paid for by the yard super, without deducting the wood framing or quartering. Each yard super requires about forty-five stock bricks and $\frac{3}{4}$ cubic foot of mortar; or thirty bricks and $\frac{1}{2}$ cubic foot of mortar, if the bricks are on edge.

Rough cutting to splays, cutting and rubbing, and other descriptions of work, are paid for according to their character—see War Department Schedules or any Standard Price Book—as in cutting the bricks to any curved line, such as to the extrados of an arch over a door or window head; in such cases the rough cutting in the body of the wall is paid for by the foot super, and the more careful cutting to the face work by the foot run, as the latter only extends to the outer $4\frac{1}{2}$-inch facing of the wall.

Except bricks, in Schedules of prices, implies that all the materials, labour, and scaffolding are supplied by the contractor, but not the bricks.

Labour only implies that all materials are supplied to the contractor, even for the scaffolding.

Estimating Labour.—In apportioning *task-work* and *piece-work*, as well as in judging whether a fair amount of work is done in return for the time expended, it may be reckoned that in building foundation and other walls, where the joints are left rough, a bricklayer, supplied with materials by his labourer, can lay 1500 or 1600 bricks in a day of ten hours' work.

In boundary and other walls, where both faces have to be worked fair, not more than 1000 per diem can be laid, and if they are carefully jointed and faced with picked bricks of a uniform colour, not more than 500 per diem, and then only if it is straight walling without many openings, which involve extra care, besides the labour of cutting the closers—Kelly and Co., *Practical Builder's Price Book.*

Gauthey gives the work of a man in days, per cubic yard, as follows :—

	Bricklayer.	Labourer.	Erecting Scaffolding.
Ordinary brickwork . .	0·6	0·6	0·2
Brick arching . .	0·9	0·9	various.

For all ordinary purposes it may be roughly assumed that a bricklayer and his labourer can turn out 2 cubic yards per diem, containing nearly 800 bricks, but as the Trades Unions do not allow their members to lay anything like the number of bricks a good bricklayer could if he tried, it would not be safe, with civil labour, to reckon on much more than half the work which the above data would lead you to expect.

Constants of labour, as well as the data necessary for estimating the amount of materials required, for almost any description of bricklayer's work, may be found in Hurst's *Architectural Surveyor's Handbook*, and, therefore, will not be enlarged upon here.

CHAPTER II.

MASON'S WORK.

A MASON, properly speaking, means a builder, which is evident from the connection between the French words *maçon,* a mason; *maison,* a house; and *maisonner,* to build houses; but in England it is customary to look upon a mason and a stone-mason as one and the same, a builder in bricks being always called a bricklayer. In Ireland the term masonry is specially applied to stone-walling, as distinguished from the cut stonework used in dressings and other work of a superior description.

In general terms, the War Department Schedules for Mason's Work are intended to provide for the execution of all the stonework required in the erection and fitting up of War Department buildings, including providing the stone in block, working and dressing it up as may be required, and setting it in its place; though hoisting above 30 feet is generally paid for as an extra.

Under the head of Mason's Work may be included that of the

Stone-cutter.
Granite mason.
Freestone mason.
Marble mason, Carver and Statuary.
Wall or Rubble mason, or Waller.

In order to be a good judge of masonry, both as regards its quality and cost, it is necessary to be familiar with the materials employed and the treatment they undergo, from their position in the quarry to their final setting in the building.

The question of materials being dealt with elsewhere, the practical operations connected with stonework of various kinds will be entered upon at once, taking first, under the head of "Work on Stone," the work put upon stone, before setting, by the stone-cutter, granite, and other masons; and after that, the wall mason's work, under the head of "Building in Stone."

Work on Stone.

General terms in use.—The *face* of a stone means the surface exposed to view.

The *beds* are the surfaces which transmit the pressures; the *natural beds* of the stone being the surfaces which correspond in direction with its planes of stratification.

The *back, side-joints,* and *bed-joints* require no explanation.

Dressing stone implies putting any particular description of work or finish upon its surface, after it has been brought to the required shape. There are many ways of dressing stone, differing according to its hardness and the custom of the locality, the same description of work being frequently known under distinct names in different places; however, the following explanations embrace the principal kinds of work on ordinary building stones, and the terms most commonly used:—

Stone-Cutter.

The *stone-cutter* takes the cube stones, or stone in rough blocks as received from the quarry, and cuts, hews, or splits it, according to its nature, into suitable dimensions for the mason or carver.

Splitting Stone.—In the case of hard stones such as granite, gritstone, etc., the large blocks are split up by sinking notches, or *pool-holes*, along the proposed line of fracture, at distances apart varying with the obstinacy of the stone, and driving *gads* and *wedges* of iron into them, or by means of iron *plugs* and *feathers.* See Figs. 48-50. The pool-holes are either sunk with a *jumper*, a long bar of iron with a steel-cutting edge like a chisel, worked by one man, who merely raises it, slightly turns it, and lets it fall by its own weight alone; or with a similar but shorter bar, called a *boring bit,* which is held and turned by one man, while another keeps up a succession of blows upon it with a heavy sledge of about 14 lbs., or a boring hammer of about 10 lbs. Single-hand boring bits and hammers, light enough to be both worked by the same man, are also used when the stone is not too hard.

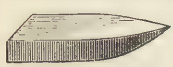


Fig. 48.—Gad.

Fig. 49.—Wedge.

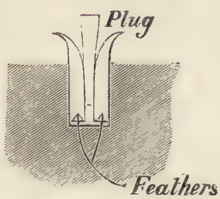


Fig. 50.

Most stones have certain planes of cleavage along which they split more kindly than in other directions, and these planes of cleavage are chiefly known to quarrymen by their direction with reference to the natural joints and lines of stratification, if any, in each particular quarry. Some stones, such as the Penmeanmawr stone, which is a kind of trap, may, while *green* or fresh from the quarry, be easily split up by cutting a fine line with an axe in the direction required, and then giving the stone a few smart taps with the hammer.

Scabbling.—The stones, having been got out of the quarry, are reduced to a closer approximation to the required dimensions by *scabbling*—sometimes called *scappling*—or roughly dressing them with the *scabbling* hammer (Fig. 51), or the *spalling* or

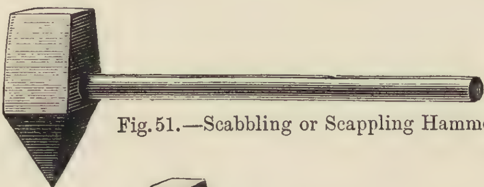


Fig. 51.—Scabbling or Scappling Hammer.

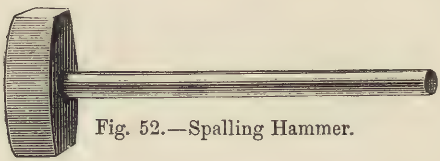


Fig. 52.—Spalling Hammer.

quarryman's hammer (Fig. 52); the scabbling hammer for granite weighing about 22 lbs., and having one flat or *spalling* face of about $4\frac{1}{2}$ by $1\frac{1}{2}$ inches for knocking off the irregular angles, the other being pick-faced, or pointed, for the purpose of reducing the surface irregularities. This work is generally done at the quarry, in order to reduce the cost of carriage.

Sawing.—The more valuable stones, when they will admit of it, are sawn into slabs and scantlings, either by hand or by machinery.

In the case of hard stones, such as Portland, Bramley Fall, Craigleith, and marbles, a toothless cross-cut saw (Fig. 53), sometimes slightly jagged at the edge, is employed, which, when drawn backwards and forwards, cuts the stone by its own weight, the operation being greatly facilitated by some clean sharp sand which is carried into the saw cut by water trickling down an inclined plane.

Granite is sometimes sawn into slabs for panels, tables, and

chimney-pieces; it is a very tedious operation, the rate of progress, by the ordinary hand process, being about $\frac{1}{2}$-inch per day of ten hours.

Blocks of soft stone, such as Bath stone, are sawn into scantlings

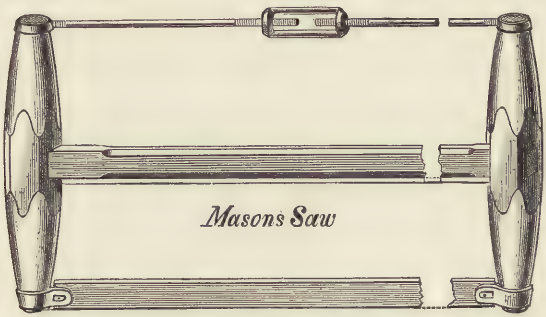


Fig. 53.

by means of an ordinary two-handed toothed saw; or, for small pieces, a common carpenter's saw is often employed.

Granite Mason.

Granite is dressed by means of heavy picks and axes, after having been roughly shaped with the scabbling hammer. Mouldings, rebates, etc., are cut by means of iron chisels steeled at the cutting edges, and used with a small hand hammer, called a *mash hammer* (Fig. 54).

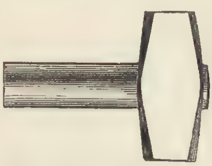


Fig. 54.—Mash Hammer.

Granite, grit, and other hard stones, built into walls with their faces merely scabbled, are said to be *quarry-pitched, hammer-faced,* or *hammer-blocked.* Such work is called *rock,* or *rustic work,* and is mostly confined to foundations, plinths, and quoins, where a bold massive appearance is aimed at.

The following are the different kinds of work put upon granite in Aberdeen; other hard stones are dressed in a somewhat similar manner:—

Hammer-dressed.—*Hammer-faced, hammer-dressed,* or *hammer-blocked* work is done with the scabbling or spalling hammer. Thus squared stones for the quoins or face of a wall, merely left rough from the hammer, as at the centre of Fig. 55, would be termed *hammer-faced ashlars;* the term ashlar, in such a case, being taken to mean squared blocks 12 inches deep on face, and

upwards—squared stones under 12 inches deep being called *shoddies*.

Scabbled.—*Scabbled* or roughly picked, with a pick, such as in Fig. 56, sometimes called a *scabbling* pick, and weighing about

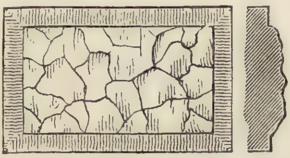


Fig. 55.

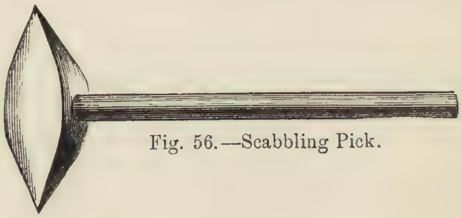


Fig. 56.—Scabbling Pick.

20 lbs., which takes down the excessive irregularities on hammer-faced work.

Punched.—*Punched* or *puncheoned*, or worked to a finer face with a blunt pick (Fig. 57), called a *punch* or *puncheon*.

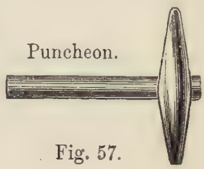


Fig. 57.

Picked.—*Picked*, or brought to a finer face with the pick, Fig. 56.

Close Picked.—*Close* or *finely picked, dabbed* or *daubbed*, done with a fine-pointed pick, or with a serrated pick, as in Fig. 58, leaving a surface as smooth as the process will admit of.

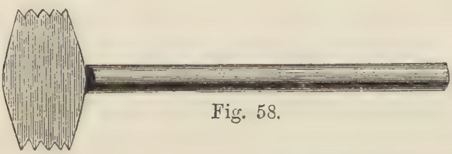


Fig. 58.

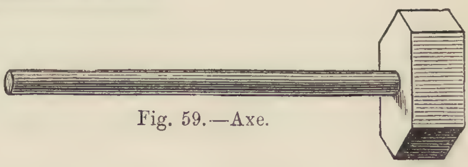


Fig. 59.—Axe.

Draughted Margins.—It is usual to run a *draught*, or smooth surface an inch or more in breadth, round the margins of squared stones, even when dressed only with the hammer or pick, in order to insure close-fitting joints, Fig. 55. The stones are then said to be hammer-faced, or, as the case may be, with *draughted margins*. These margins are wrought with the axe as in *single* and *fine axing*.

Single axed.—In this work the inequalities left by the pick are reduced by an axe, weighing about 9 lbs., Fig. 59. Axed work

shows the marks of the tool in parallel lines, and is used in quoins, rebates, cornices, etc.

Fine axed.—*Fine axed* is a more careful description of single axed work.

Patent axed.—*Patent axed* is the finest description of surface-work before polishing, and is produced with a hammer or axe, the faces of which are formed of a number of parallel thin steel

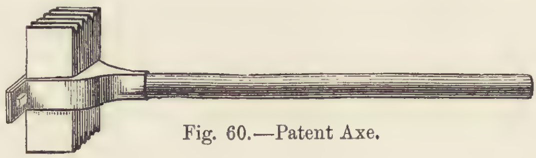


Fig. 60.—Patent Axe.

blades bound together so as to allow of their being taken out and resharpened, Fig. 60.

Polished.—This is performed by rubbing—first with fine sand and water, under an iron rubber, then with emery, and, lastly, with putty and flannel.

All plain surfaces and running mouldings can be done by machinery, but carvings and broken surfaces have to be done by the hand.

Hard stones, such as granite, show off to best advantage when polished; but if such a high finish is considered too costly, it is better not to waste money upon too fine a face, which only destroys the beauty of the grain, and produces a flat, monotonous, surface.

Freestone Mason.

Freestone is the term given to such building stones as admit of being freely worked by the mason with his *mallet* and *chisels*, and consequently applies to the greater number of sand and limestones. The principal tools employed at the mason's *banker*, or stone bench, are as follows:—

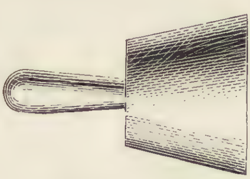


Fig. 61.—Mallet.

Tools.—*Mallet* of wood (Fig. 61), used for striking the cutting tools.

Pitching tool (Fig. 62) of iron, steeled at the end, with a bevelled instead of a cutting edge; used with the mash hammer, for knocking off the irregularities along the edge of a stone.

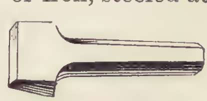


Fig. 62.—Pitching Tool.

Points (Fig. 63) and *punches* of iron, steel-

pointed, for picking or punching the surface, from a sharp point to about $\frac{1}{4}$-inch broad. The point is worked with the mallet, and punches, which are blunt points, with the mash hammer.

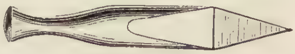


Fig 63.—Point.

Chisels (Fig. 64), or tools of iron with steel-cutting edges, $\frac{1}{4}$-inch broad and upwards, going by different names, such as—the *inch tool;* the *boaster,* which is at least 2 inches broad; the *broad tool,* from 3 to 4 inches broad; and others of intermediate sizes.

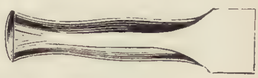


Fig. 64.

The term *chisel* is, about London and other localities, applied only to cutting tools from $\frac{1}{4}$ to 2 inches broad, those above 2 inches being classed as *tools* or *boasters.*

For setting out work masons use *rules, straight-edges, squares, bevels,* and *templets,* called *moulds* when the work is moulded.

Cut-stone Work.—The stones intended for the cut-stone work in a building are brought to the mason's banker in blocks of the required dimensions, either *scabbled* or *sawn,* as the case may be.

The following extract (*Art of Building,* Virtue and Co.'s Series, par. 203) explains the practical operations involved in taking the face of a stone *out of winding,* or bringing it to a level surface; as well as in cutting it to any required shape, as for mouldings:—

"In stone-cutting the workman forms as many plane faces as may be necessary for bringing the stone into the required shape, with the least waste of material and labour, and on the plane surfaces so formed applies the moulds to which the stone is to be worked.

"To form a plane surface, the mason first knocks off the superfluous stone (beginning from the lowest corner) along one edge of the block, as *a b* (Fig. 65), until it coincides with a straight-edge throughout its whole length: this is called a *chisel draught.* Another chisel draught is then made along one of the adjacent edges, as *b c,*

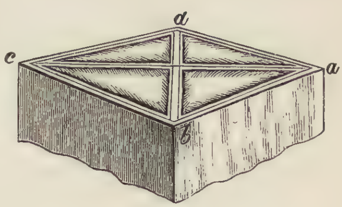


Fig. 65.

and the ends of the two are connected by another draught, as *a c*; a fourth draught is then sunk across the last, as *b d,* which gives another angle-point *d,* in the same plane with *a, b,* and *c,* by which the draughts *d a* and *a c* can be formed; and the stone

is then knocked off between the outside draughts until a straight edge coincides with its surface in every part.

"To form cylindrical or moulded surfaces curved in one direction only, the workman sinks two parallel draughts at the opposite ends, *a, a,* of the stone (Fig. 66) to be worked, until they coincide with a mould cut to the required shape, and afterwards works off the stone between these draughts, by a straight-edge applied at right angles to them.

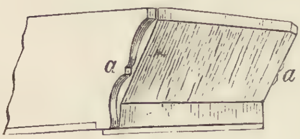


Fig. 66.

"The formation of conical or spherical surfaces is much less simple, and requires a knowledge of the scientific operations of stone-cutting, a description of which would be unsuited to the elementary character of these pages. The reader who wishes to pursue the subject is therefore referred to the volume of this series on *Masonry and Stone-Cutting,* where he will find the required information."

Dressing hard Freestone.—There are many varieties of surface-work, the names given to them differing very much with the locality; the following, however, may be taken as those frequently put upon the harder kinds of freestone. The dressing of soft freestone, being a much simpler matter, will be explained separately.

Hammer Dressing.—Hammer dressing is the roughest description of work after scabbling, and consists of getting rid of any excessive irregularities on the surface of the stone, with a much lighter hammer than the scabbling hammer, one face being flat for roughly shaping the stone, and the other axe shaped for smoothing or hammer-dressing the surfaces. It generally goes by the name of the *waller's hammer* (Fig. 67), and is capable of being used with either one or two hands as may be required.

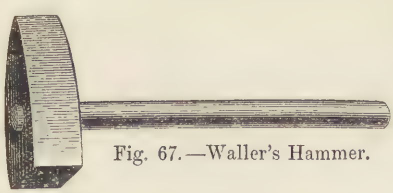


Fig. 67.—Waller's Hammer.

Half-Plain Work.—This is a term applied in War Department Schedules to such work as to the joints of cut-stone work, when left as they came from the saw; or to roughly-picked or hammered surfaces brought to a sufficiently smooth condition for ordinary joints, by dressing them down with the punch or point, leaving the marks of the tool all over the surface. In preparing joints,

any irregularities left by the point, above the plane of the joint, are finally dressed down with a chisel or boaster.

Plain Work.—Plain, chiselled, or random-tooled work is simply chiselling down the inequalities left by the saw, punch, or point, leaving the chisel marks running at random all over the surface of the stone. The broader the chisel used, the smoother the surface will be.

Pointed Work, called in Scotland *dabbed* or *daubbed work,* is bringing the faces of stones to a regular surface by picking them all over with the point, the marks of the tool running generally in lines at right angles to the bedding of the stone, or at random when the stone has no distinct bedding. It has a pock-marked appearance (Fig. 68), may be worked to a great degree of fineness,

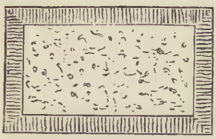


Fig. 68.

Fig. 69.—Boasted or Droved Work.

Fig. 70.—Tooled Work.

and is always *chisel-draughted* round the margins or edges. When worked to a coarser surface, with a punch, it is called *punched work.*

Boasted Work, called in Scotland *droved* work (Fig. 69), is a more regular description of chiselling, in which the marks of the boaster run in parallel lines, each successive stroke being made beneath the last, down the whole length of the stone. The same operation is repeated till the marks extend over its whole breadth.

Tooled Work.—Tooled work (Fig. 70) is similar to the last, except that each stroke of the broad tool is made by the side of the last, so as to form a series of parallel lines, each line extending across the whole breadth of the stone. It is, however, much more troublesome to do, as the surface has first to be worked smooth with the chisel.

Stroked work, or *striped work,* is similar to tooling, except in the direction of the lines, which run at an angle of about 45°, instead of parallel to the edges of the stone.

Rubbed work, or *polished work,* as it is very frequently called, is plain work rubbed down with freestone, sand, and water, to a perfectly smooth surface. In preparing the surface for rubbing, it should be pointed to as true a face as possible, and then dressed smooth with a boaster or broad tool; or the latter only, if the stone is soft, will suffice.

Marble is polished by being rubbed with grit or sandstone, then with pumice stone, and finally with emery or calcined tin. The rubber is about 3 inches square, of $\frac{1}{8}$ to $\frac{1}{2}$ inch felt cemented to an inch-piece of wood, so as to give a good hold to the hand.

Dressing soft Freestone.—Softer stones, such as Bath stone, are always finished to a much smoother face than harder stones, as any attempt at producing an effect by roughly dressing them would soon be effaced by the action of the weather. The only dressing generally bestowed on them is *dragging* them with a *drag* or *comb* (Fig. 71), to get rid of the inequalities left by the saw or chisel. The drags used may be pieces of an old saw, with coarse or fine teeth according to the smoothness required. Some stones, which are too tough and cheesy for dragging, are shaved with a common carpenter's chisel, as in wood-carving.

Fig. 71.—Drag or Comb.

In dressing the surfaces of soft stones there is no scabbling, chiselling, rubbing, etc., though chisels are used in shaping the stones and working mouldings, etc.

Scamping Cut-stone.—Masons are apt to scamp cut-stone work by disguising cracks, chipped arrises, and wants or hollows in stones, by means of a composition, instead of working down the whole surface of the stone below such imperfections. For this purpose they will pound up a piece of the stone and mix the stone dust with melted resin or brimstone, which, when pressed into any want, will soon harden and admit of being worked like the rest of the stone.

With Bath stones some of the dust is mixed cold with shellac and naphtha to fill up any imperfections, and pieces of Bath stone are sometimes even joined together with shellac and naphtha. A little careful examination will generally detect such tricks as these.

Carver.

The carver's work, as well as that of the marble mason and statuary, forms a special branch of the trade, and comprises the production of such parts as enriched cornices, capitals, etc., and is necessarily valued by the time expended upon it; the value of the time varying, in the higher class of carvings, with the artistic reputation of the man employed.

Building in Stone.

Wall Mason or Waller.—The wall mason builds all stone constructions, and, from the irregular shapes and sizes of the materials generally at his command for building purposes, is constantly called upon to exercise an amount of judgment and skill far beyond what is required to make a good bricklayer, who mostly lays his regular shaped bricks according to fixed rules, which he knows by heart, and ought not to depart from. The rougher the materials, the more skill is required in putting them together; whilst the greater the preliminary labour in dressing them to regular shapes the easier the wall mason's task becomes.

Tools.—The following tools are used by masons in setting stones in place, viz.: *trowels, setting bar, lines and pins, square, level, plumb and battering rules,* as used by bricklayers; also a *fish,* used largely in France, to spread the bedding mortar under large stones—it has a long flat steel blade, saw-edged on both sides, like the snout of a sword-fish, with a handle at one end.

The following is from Rankine's *C. Eg.*, par. 252, 5th ed.:—

"When the face of the wall is to have '*a straight batter*'—that is, to be inclined at a uniform angle to the vertical—the rule to be used is still straight-edged, but the edge is inclined to the plumb-line at the proper angle of batter. The batter of a wall is usually described by its deviation from the vertical in a given height; for example, 'one in twelve,' or 'one inch to the foot.'

"When the vertical section of the face of a wall is to be curved, it is said to have a *curved batter,* and it must be set out by means of a *face-mould,*—that is to say, a narrow, flat, board, having one of its edges of the intended figure of the face of the wall, and having a straight line marked upon it, which is set truly vertical by means of a plummet. Great care should be bestowed on preparing the face-moulds of important pieces of masonry; in some cases, every course of stones ought to be marked on the edge of the mould.

"Large face-moulds are sometimes made of several pieces of timber framed together.

"When the beds of the courses are to be plane and level, they can be set correctly by the level and common straight-edge. When they are to be planes having a given slope, a rule must be employed having two straight edges inclined to each other at such an angle that, when one edge is set horizontal by the spirit-

level, the other has the proper inclination. If the beds of the courses are to be perpendicular to a straight or curved battering face, their position can be set out and tested by the square.

"Curved beds, such as are employed for some special purposes, require the use of suitably curved *bed-moulds.*

"In all cases in which economy of time and money has to be studied, the engineer should, as far as practicable, avoid curved figures in masonry; for not only are they more tedious and expensive to set out and to build than straight and plane figures, but it is more difficult to test the accuracy with which they have been executed. A single glance will detect the smallest appreciable inaccuracy in a wall with a straight batter, while the same process in the case of a wall with a curved batter would require either a long series of measurements, or the application of a cumbrous face-mould to various parts of the wall; and this becomes a matter of serious importance in large structures, where errors in form may affect the strength and stability."

Scaffolding.—For the rougher descriptions of walling, a scaffolding similar to that erected by bricklayers is used; but, as putlog holes would disfigure the better descriptions of masonry, a second row of standards has to be put up to carry the inner ends of the putlogs.

In large works the scaffolding, which thus stands independent of the building, is built up of square timbers connected together by bolts and *dog irons,* and well braced diagonally. The returned ends of the *dog irons* should be sloped on the inside, as shown at A (Fig. 72), and not as at B, in order to draw the timbers together when driven home.

Fig. 72.

Designing and erecting scaffolding for works of great size requires so much skill and practice that it has come to be regarded as a special business by itself.

Travellers.—In order to raise heavy blocks of stone, etc., and place them in position, a *traveller* or travelling platform (Fig. 73), may be made to run on a raised tramway, called a *gantry* or *gantree,* formed by laying rails along the top of two parallel beams supported on two rows of standards, on opposite sides of the building, so as, if possible, to span the whole site of the work.

The traveller usually consists of two iron, or wooden, trussed girders, fixed parallel to each other, 3 or more feet apart; along the top of which a four-wheeled truck runs on rails, carrying a

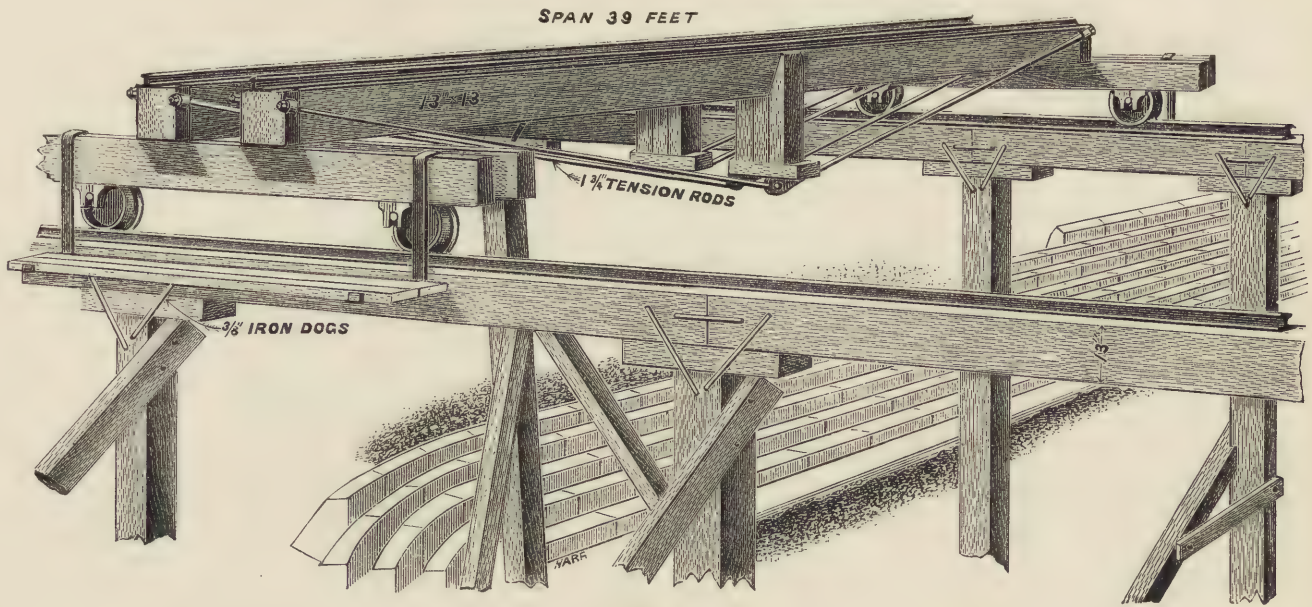


Fig. 73

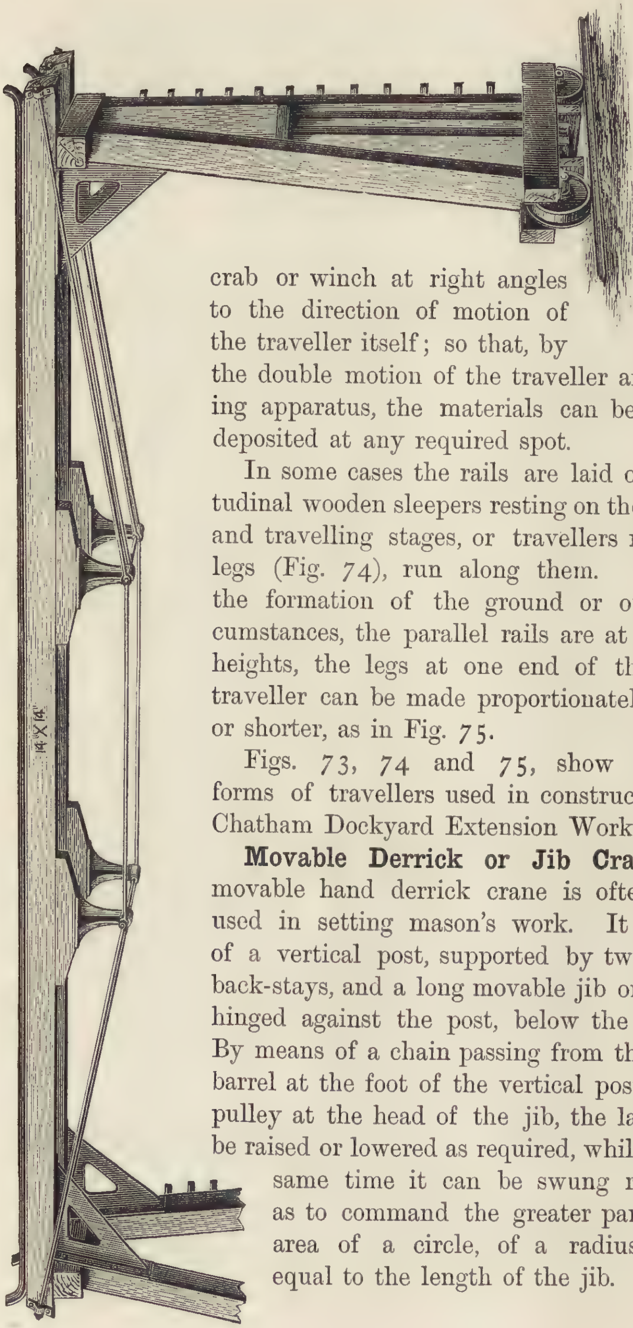


Fig. 74.

crab or winch at right angles to the direction of motion of the traveller itself; so that, by the double motion of the traveller and hoisting apparatus, the materials can be rapidly deposited at any required spot.

In some cases the rails are laid on longitudinal wooden sleepers resting on the ground, and travelling stages, or travellers raised on legs (Fig. 74), run along them. If, from the formation of the ground or other circumstances, the parallel rails are at different heights, the legs at one end of the raised traveller can be made proportionately longer or shorter, as in Fig. 75.

Figs. 73, 74 and 75, show different forms of travellers used in constructing the Chatham Dockyard Extension Works.

Movable Derrick or Jib Crane.—A movable hand derrick crane is often much used in setting mason's work. It consists of a vertical post, supported by two timber back-stays, and a long movable jib or derrick hinged against the post, below the gearing. By means of a chain passing from the lifting barrel at the foot of the vertical post, over a pulley at the head of the jib, the latter can be raised or lowered as required, whilst at the same time it can be swung round so as to command the greater part of the area of a circle, of a radius nearly equal to the length of the jib.

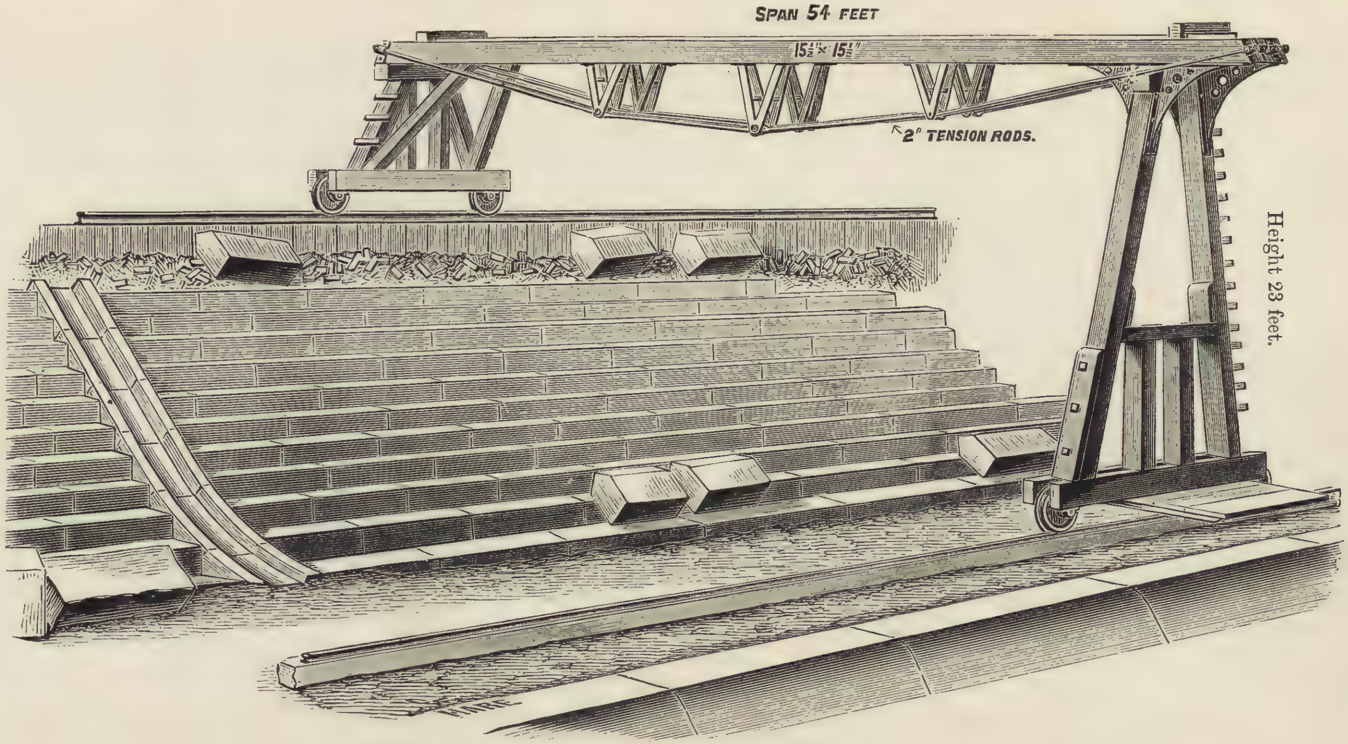


Fig. 75.

For sketches and prices of travellers, cranes, etc., see Appleby's *Handbook of Machinery;* Bolling and Lowe's *Price Book,* etc.

Holders for Stones.—There are various ways of laying hold of stones which are too heavy to be moved by hand. The following are those most frequently used:—

Nippers.—A pair of nippers or iron claws or hooks, as in Fig. 76, the ends of which catch in holes or on knobs, one in each side of the block, in the same vertical plane as, and at a convenient distance above, the centre of gravity of the block.

Single Plug.—A single iron plug very slightly tapered, and driven into a cylindrical hole directly over the centre of gravity

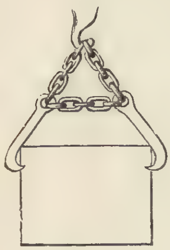


Fig. 76.

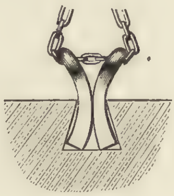


Fig. 77.

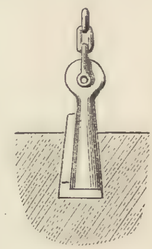


Fig. 78.

of the stone. By this simple means hard stones such as granite may be lifted with ease, a few side taps being sufficient to loosen the plug, when required to be withdrawn.

Double Plug.—Two curved iron plugs, with a chain passing through eyes in their heads, placed in a dovetailed hole, directly over the centre of gravity of the stone, as shown in Fig. 77.

Plug and Wedge.—An iron conical plug with an eye at the top, for a chain or hook to pass through, placed in a rather larger conical hole, directly over the centre of gravity of the stone, with an iron key piece—curved so as to fit the plug and the circumference of the hole—slipped in by its side, as in Fig. 78. This plug was used for setting the heavy granite coping on the Thames Embankment wall.

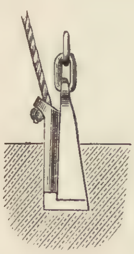


Fig. 79.

The plug may be rectangular instead of round, as shown on Fig. 79; and in laying blocks under water can be released, from the surface, by first drawing the side key by means of a cord attached to its head.

Lewis.—A *lewis* or iron dovetail, as in Fig. 80, made in three pieces; the two outer pieces *a a*, being first dropped into a corresponding dovetailed hole cut in the stone, directly over its centre of gravity, then the centre piece slipped in between them, the suspending tackle put in its place, and finally a bolt passed through the whole and keyed up.

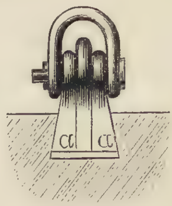


Fig. 80.

Principles of Stone-Laying.—The following observations apply to masonry constructions of every description:—

Bedding Stones.—All stones, except under peculiar circumstances, should be laid on their *natural* or *quarry beds*, or with their natural beds as far as possible perpendicular to the pressure they have to bear.

The strength and durability of the stone depends on this being done—even in cases, such as Bath stone, in which the natural beds cannot be distinguished by an unpractised eye—for few stones will bear the same pressure applied in the direction of their lines of stratification as at right angles to them; moreover, if the bed of a stone is exposed on the face of a wall, the water will get in between its layers, and frost will soon cause layer after layer to peel off; hence it follows that in projecting undercut mouldings and weathered copings, the natural beds should be placed parallel to the side-joints.

Bond in Masonry.—The careful bonding of the masonry must be attended to. A wall built of the roughest stones ought to be perfectly stable, though no mortar is used.

The principles of bond, by the stones overlapping and breaking joint throughout the wall, are the same as in brickwork, and should be thoroughly understood by the mason, for upon their skilful application his reputation as a good *waller* depends.

Wetting Stones.—All dry and porous stones should be well wetted before being laid in mortar, so as not to absorb the moisture required for the proper setting of the mortar.

Joints of Masonry.—All joints should be filled up solid with mortar.

The thickness of the bed-joints, depending on the smoothness of the beds, must be sufficient to prevent any unequal bearing resulting from actual contact between any irregularities on them.

Stains on Stones.—Where a good appearance is aimed at, all

stones exposed to view should be selected free from stains, chiefly caused by oxides of iron.

Iron in Stonework.—Iron should never be placed in contact with stonework where, by rusting, it might disfigure it with stains, or split the stone by its increase in bulk during the process of oxidation, or by its expanding and contracting under the influence of heat and cold.

Different kinds of Masonry.—In order to understand the practical operations of building in stone, it is necessary to explain the different descriptions of masonry in ordinary use. These may all be included under one of the three following heads, viz.:—

Rubble.
Block-in-Course.
Ashlar.

If the stone at disposal is thinly bedded, rough or intractable, it should be used as *rubble-work;* if obtainable in blocks, and more or less easily wrought, it should be used as *block-in-course* or *ashlar*, according to circumstances.

Rubble Masonry.

In *rubble-work* stones of irregular size and shape are laid in a wall, after having been more or less assorted, roughly shaped to fit one against another, and hammer dressed on their faces with the waller's hammer, according to the quality of the work required.

In the rougher kinds of rubble-work no selecting of the stones takes place, but the waller, having once taken one up, places it in the wall as it will lie best, packing in smaller stones between the larger ones. The stones should be placed on their best beds, and not on their points, which would be liable to crush, in addition to the wedge-like action of such stones in the interior of a wall tending to dislodge the facework. No attention whatever is paid to the joints being more horizontal or vertical than naturally results from the bedding and cleavage of the stone used, upon which the degree of regularity in the appearance of the work mainly depends.

In rubble masonry the rough nature of the work leaves many spaces between the joints, both on the face and interior of the wall; these should be carefully packed up or *pinned* with *spalls;*

which are the pieces knocked off the rougher stones, in order to get them to fit into place.

Care should be taken that the *hearting* or interior of a rubble wall is well packed with spalls and mortar, and not left full of hollows or mortar alone; to ascertain whether this has been done, take the waller's trowel and plunge it in different places into the heart of the wall.

The spalls must not be placed in the heart of the wall so as to drive like wedges when the weight from above comes on them, or the facing stones will be forced out.

Attention is necessary during the building of rubble, as well as all masonry walls, to insure their being well bonded transversely, and not built up with two thin scales on each face, tied together by *through* stones, with the core or hearting merely filled in with small pieces. This is a very common fault with masons, who will rely upon the mortar to give stability to a wall which, without it, would fall to pieces under its own weight.

The best stones for rubble masonry are those that scabble freely, and such as lie in 4 or 5 inch beds. Basalts and stones of a crystalline structure are troublesome to use, as they fly under the hammer, but granite and sandstones work in well.

Rubble may be either *uncoursed—irregular* or *random coursed—worked up to courses*—or *coursed*—chiefly depending upon the character of the stone at disposal. Some stones, such as Kentish rag, from their intractable nature, and the absence of any distinct lines of bedding, are specially adapted for *uncoursed* rubble; whilst others readily work into courses, and therefore should be used as *coursed* rubble.

Uncoursed Rubble.—In *uncoursed, random, rough,* or *common rubble* (Fig. 81) the stones are laid at random—without being brought up to any level courses—the only tools required being a trowel, waller's hammer, and plumb or battering rules, as the case may require.


Fig. 81.—Common Rough Uncoursed or Random Rubble.

One bond stone should be used to at least every yard super of the face, and they should run about $\frac{2}{3}$ to $\frac{3}{4}$ through the wall, alternately from the opposite sides; this,

in the case of dwelling-houses, diminishes the chances of damp being transmitted to the interior, and is in all cases much preferable to a smaller number of *through* stones, though in boundary and similar walls, *through* stones are more generally used. In thick walls, such as piers, abutments, and retaining walls, the bond stones should tail into the work as far as possible, and the whole should be bonded together in the best way the sizes of the blocks will admit of.

It is necessary to see the bond stones actually built into the wall, for builders are apt to set large stones on edge, running only 3 or 4 inches into the wall, instead of true bond stones—a trick which cannot well be detected after they have once been covered up.

Flint or river pebbles, or *popples* as they are sometimes called, are often used for this class of work, either laid in their natural forms or *polled*, that is, split, and their fractured surfaces shown on the face of the work, by which means a smoother and more finished face is obtained, and the rain can run down with less chance of getting into the body of the work. When walls are built up of such materials, brickwork, or masonry of a more regular description, should be used at the quoins or angles, and a few horizontal courses or bands of the same should, at vertical intervals, run through the whole thickness of the wall, to assist in tying it all together.

There is a superior description of uncoursed rubble much used

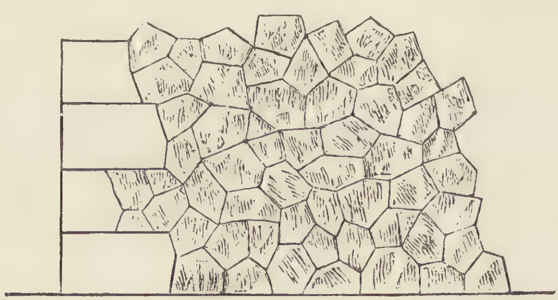


Fig. 82.—Random Rubble with Hammer-Dressed Joints and no Spalls on Face.

in ecclesiastical achitecture, which generally goes by the name of *rustic* or *random work*, in which no spalls should be seen on the face of the wall, and no horizontal or vertical joints are to be found. The stone employed for this class of masonry, such as

upwards—squared stones under 12 inches deep being called *shoddies.*

Scabbled.—*Scabbled* or roughly picked, with a pick, such as in Fig. 56, sometimes called a *scabbling* pick, and weighing about

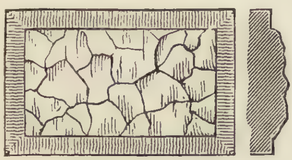


Fig. 55.

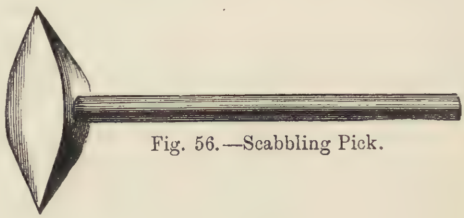
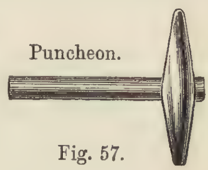


Fig. 56.—Scabbling Pick.

20 lbs., which takes down the excessive irregularities on hammer-faced work.

Punched.—*Punched* or *puncheoned*, or worked to a finer face with a blunt pick (Fig. 57), called a *punch* or *puncheon.*



Puncheon.

Fig. 57.

Picked.—*Picked*, or brought to a finer face with the pick, Fig. 56.

Close Picked.—*Close* or *finely picked, dabbed* or *daubbed*, done with a fine-pointed pick, or with a serrated pick, as in Fig. 58, leaving a surface as smooth as the process will admit of.

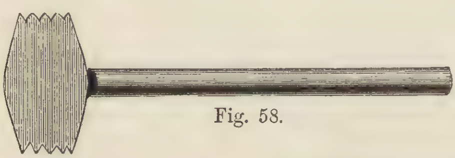


Fig. 58.

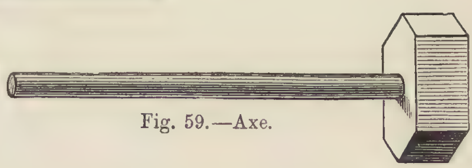


Fig. 59.—Axe.

Draughted Margins.—It is usual to run a *draught*, or smooth surface an inch or more in breadth, round the margins of squared stones, even when dressed only with the hammer or pick, in order to insure close-fitting joints, Fig. 55. The stones are then said to be hammer-faced, or, as the case may be, with *draughted margins.* These margins are wrought with the axe as in *single* and *fine axing.*

Single axed.—In this work the inequalities left by the pick are reduced by an axe, weighing about 9 lbs., Fig. 59. Axed work

shows the marks of the tool in parallel lines, and is used in quoins, rebates, cornices, etc.

Fine axed.—*Fine axed* is a more careful description of single axed work.

Patent axed.—*Patent axed* is the finest description of surface-work before polishing, and is produced with a hammer or axe, the faces of which are formed of a number of parallel thin steel

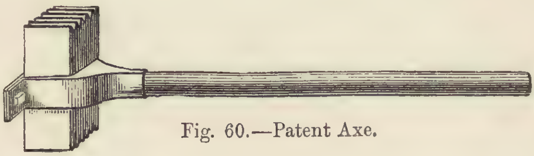


Fig. 60.—Patent Axe.

blades bound together so as to allow of their being taken out and resharpened, Fig. 60.

Polished.—This is performed by rubbing—first with fine sand and water, under an iron rubber, then with emery, and, lastly, with putty and flannel.

All plain surfaces and running mouldings can be done by machinery, but carvings and broken surfaces have to be done by the hand.

Hard stones, such as granite, show off to best advantage when polished; but if such a high finish is considered too costly, it is better not to waste money upon too fine a face, which only destroys the beauty of the grain, and produces a flat, monotonous, surface.

Freestone Mason.

Freestone is the term given to such building stones as admit of being freely worked by the mason with his *mallet* and *chisels*, and consequently applies to the greater number of sand and limestones. The principal tools employed at the mason's *banker*, or stone bench, are as follows:—

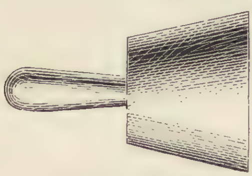


Fig. 61.—Mallet.

Tools.—*Mallet* of wood (Fig. 61), used for striking the cutting tools.

Pitching tool (Fig. 62) of iron, steeled at the end, with a bevelled instead of a cutting edge; used with the mash hammer, for knocking off the irregularities along the edge of a stone.

Fig. 62.—Pitching Tool.

Points (Fig. 63) and *punches* of iron, steel-

pointed, for picking or punching the surface, from a sharp point to about $\frac{1}{4}$-inch broad. The point is worked with the mallet, and punches, which are blunt points, with the mash hammer.

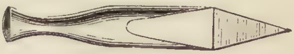


Fig 63.—Point.

Chisels (Fig. 64), or tools of iron with steel-cutting edges, $\frac{1}{4}$-inch broad and upwards, going by different names, such as—the *inch tool;* the *boaster,* which is at least 2 inches broad; the *broad tool,* from 3 to 4 inches broad; and others of intermediate sizes.

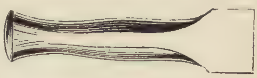


Fig. 64.

The term *chisel* is, about London and other localities, applied only to cutting tools from $\frac{1}{4}$ to 2 inches broad, those above 2 inches being classed as *tools* or *boasters.*

For setting out work masons use *rules, straight-edges, squares, bevels,* and *templets,* called *moulds* when the work is moulded.

Cut-stone Work.—The stones intended for the cut-stone work in a building are brought to the mason's banker in blocks of the required dimensions, either *scabbled* or *sawn,* as the case may be.

The following extract (*Art of Building,* Virtue and Co.'s Series, par. 203) explains the practical operations involved in taking the face of a stone *out of winding,* or bringing it to a level surface; as well as in cutting it to any required shape, as for mouldings:—

"In stone-cutting the workman forms as many plane faces as may be necessary for bringing the stone into the required shape, with the least waste of material and labour, and on the plane surfaces so formed applies the moulds to which the stone is to be worked.

"To form a plane surface, the mason first knocks off the superfluous stone (beginning from the lowest corner) along one edge of the block, as *a b* (Fig. 65), until it coincides with a straight-edge throughout its whole length: this is called a *chisel draught.* Another chisel draught is then made along one of the adjacent edges, as *b c,*

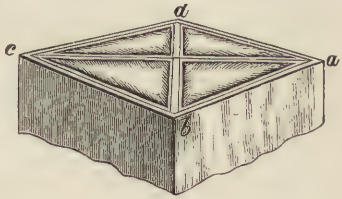


Fig. 65.

and the ends of the two are connected by another draught, as *a c*; a fourth draught is then sunk across the last, as *b d,* which gives another angle-point *d,* in the same plane with *a, b,* and *c,* by which the draughts *d a* and *a c* can be formed; and the stone

is then knocked off between the outside draughts until a straight edge coincides with its surface in every part.

"To form cylindrical or moulded surfaces curved in one direction only, the workman sinks two parallel draughts at the opposite ends, *a*, *a*, of the stone (Fig. 66) to be worked, until they coincide with a mould cut to the required shape, and afterwards works off the stone between these draughts, by a straight-edge applied at right angles to them.

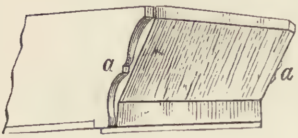


Fig. 66.

"The formation of conical or spherical surfaces is much less simple, and requires a knowledge of the scientific operations of stone-cutting, a description of which would be unsuited to the elementary character of these pages. The reader who wishes to pursue the subject is therefore referred to the volume of this series on *Masonry and Stone-Cutting*, where he will find the required information."

Dressing hard Freestone.—There are many varieties of surface-work, the names given to them differing very much with the locality; the following, however, may be taken as those frequently put upon the harder kinds of freestone. The dressing of soft freestone, being a much simpler matter, will be explained separately.

Hammer Dressing.—Hammer dressing is the roughest description of work after scabbling, and consists of getting rid of any excessive irregularities on the surface of the stone, with a much lighter hammer than the scabbling hammer, one face being flat for roughly shaping the stone, and the other axe shaped for smoothing or hammer-dressing the surfaces. It generally goes by the name of the *waller's hammer* (Fig. 67), and is capable of being used with either one or two hands as may be required.

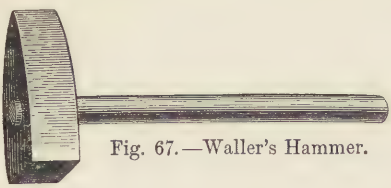


Fig. 67.—Waller's Hammer.

Half-Plain Work.—This is a term applied in War Department Schedules to such work as to the joints of cut-stone work, when left as they came from the saw; or to roughly-picked or hammered surfaces brought to a sufficiently smooth condition for ordinary joints, by dressing them down with the punch or point, leaving the marks of the tool all over the surface. In preparing joints,

any irregularities left by the point, above the plane of the joint, are finally dressed down with a chisel or boaster.

Plain Work.—Plain, chiselled, or random-tooled work is simply chiselling down the inequalities left by the saw, punch, or point, leaving the chisel marks running at random all over the surface of the stone. The broader the chisel used, the smoother the surface will be.

Pointed Work, called in Scotland *dabbed* or *daubbed work,* is bringing the faces of stones to a regular surface by picking them all over with the point, the marks of the tool running generally in lines at right angles to the bedding of the stone, or at random when the stone has no distinct bedding. It has a pock-marked appearance (Fig. 68), may be worked to a great degree of fineness,

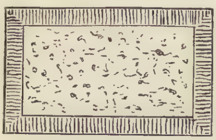


Fig. 68.

Fig. 69.—Boasted or Droved Work.

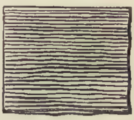


Fig. 70.—Tooled Work.

and is always *chisel-draughted* round the margins or edges. When worked to a coarser surface, with a punch, it is called *punched work.*

Boasted Work, called in Scotland *droved* work (Fig. 69), is a more regular description of chiselling, in which the marks of the boaster run in parallel lines, each successive stroke being made beneath the last, down the whole length of the stone. The same operation is repeated till the marks extend over its whole breadth.

Tooled Work.—Tooled work (Fig. 70) is similar to the last, except that each stroke of the broad tool is made by the side of the last, so as to form a series of parallel lines, each line extending across the whole breadth of the stone. It is, however, much more troublesome to do, as the surface has first to be worked smooth with the chisel.

Stroked work, or *striped work,* is similar to tooling, except in the direction of the lines, which run at an angle of about 45°, instead of parallel to the edges of the stone.

Rubbed work, or *polished work,* as it is very frequently called, is plain work rubbed down with freestone, sand, and water, to a perfectly smooth surface. In preparing the surface for rubbing, it should be pointed to as true a face as possible, and then dressed smooth with a boaster or broad tool; or the latter only, if the stone is soft, will suffice.

Marble is polished by being rubbed with grit or sandstone, then with pumice stone, and finally with emery or calcined tin. The rubber is about 3 inches square, of $\frac{1}{8}$ to $\frac{1}{2}$ inch felt cemented to an inch-piece of wood, so as to give a good hold to the hand.

Dressing soft Freestone.—Softer stones, such as Bath stone, are always finished to a much smoother face than harder stones, as any attempt at producing an effect by roughly dressing them would soon be effaced by the action of the weather. The only dressing generally bestowed on them is *dragging* them with a *drag* or *comb* (Fig. 71), to get rid of the inequalities left by the saw or chisel. The drags used may be pieces of an old saw, with coarse or fine teeth according to the smoothness required. Some stones, which are too tough and cheesy for dragging, are shaved with a common carpenter's chisel, as in wood-carving.

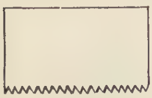


Fig. 71.—Drag or Comb.

In dressing the surfaces of soft stones there is no scabbling, chiselling, rubbing, etc., though chisels are used in shaping the stones and working mouldings, etc.

Scamping Cut-stone.—Masons are apt to scamp cut-stone work by disguising cracks, chipped arrises, and wants or hollows in stones, by means of a composition, instead of working down the whole surface of the stone below such imperfections. For this purpose they will pound up a piece of the stone and mix the stone dust with melted resin or brimstone, which, when pressed into any want, will soon harden and admit of being worked like the rest of the stone.

With Bath stones some of the dust is mixed cold with shellac and naphtha to fill up any imperfections, and pieces of Bath stone are sometimes even joined together with shellac and naphtha. A little careful examination will generally detect such tricks as these.

Carver.

The carver's work, as well as that of the marble mason and statuary, forms a special branch of the trade, and comprises the production of such parts as enriched cornices, capitals, etc., and is necessarily valued by the time expended upon it; the value of the time varying, in the higher class of carvings, with the artistic reputation of the man employed.

Building in Stone.

Wall Mason or Waller.—The wall mason builds all stone constructions, and, from the irregular shapes and sizes of the materials generally at his command for building purposes, is constantly called upon to exercise an amount of judgment and skill far beyond what is required to make a good bricklayer, who mostly lays his regular shaped bricks according to fixed rules, which he knows by heart, and ought not to depart from. The rougher the materials, the more skill is required in putting them together; whilst the greater the preliminary labour in dressing them to regular shapes the easier the wall mason's task becomes.

Tools.—The following tools are used by masons in setting stones in place, viz.: *trowels, setting bar, lines and pins, square, level, plumb and battering rules,* as used by bricklayers; also a *fish,* used largely in France, to spread the bedding mortar under large stones—it has a long flat steel blade, saw-edged on both sides, like the snout of a sword-fish, with a handle at one end.

The following is from Rankine's *C. Eg.*, par. 252, 5th ed.:—

"When the face of the wall is to have '*a straight batter*'—that is, to be inclined at a uniform angle to the vertical—the rule to be used is still straight-edged, but the edge is inclined to the plumb-line at the proper angle of batter. The batter of a wall is usually described by its deviation from the vertical in a given height; for example, 'one in twelve,' or 'one inch to the foot.'

"When the vertical section of the face of a wall is to be curved, it is said to have a *curved batter,* and it must be set out by means of a *face-mould,*—that is to say, a narrow, flat, board, having one of its edges of the intended figure of the face of the wall, and having a straight line marked upon it, which is set truly vertical by means of a plummet. Great care should be bestowed on preparing the face-moulds of important pieces of masonry; in some cases, every course of stones ought to be marked on the edge of the mould.

"Large face-moulds are sometimes made of several pieces of timber framed together.

"When the beds of the courses are to be plane and level, they can be set correctly by the level and common straight-edge. When they are to be planes having a given slope, a rule must be employed having two straight edges inclined to each other at such an angle that, when one edge is set horizontal by the spirit-

level, the other has the proper inclination. If the beds of the courses are to be perpendicular to a straight or curved battering face, their position can be set out and tested by the square.

"Curved beds, such as are employed for some special purposes, require the use of suitably curved *bed-moulds.*

"In all cases in which economy of time and money has to be studied, the engineer should, as far as practicable, avoid curved figures in masonry; for not only are they more tedious and expensive to set out and to build than straight and plane figures, but it is more difficult to test the accuracy with which they have been executed. A single glance will detect the smallest appreciable inaccuracy in a wall with a straight batter, while the same process in the case of a wall with a curved batter would require either a long series of measurements, or the application of a cumbrous face-mould to various parts of the wall; and this becomes a matter of serious importance in large structures, where errors in form may affect the strength and stability."

Scaffolding.—For the rougher descriptions of walling, a scaffolding similar to that erected by bricklayers is used; but, as putlog holes would disfigure the better descriptions of masonry, a second row of standards has to be put up to carry the inner ends of the putlogs.

In large works the scaffolding, which thus stands independent of the building, is built up of square timbers connected together by bolts and *dog irons,* and well braced diagonally. The returned ends of the *dog irons* should be sloped on the inside, as shown at A (Fig. 72), and not as at B, in order to draw the timbers together when driven home.

Fig. 72.

Designing and erecting scaffolding for works of great size requires so much skill and practice that it has come to be regarded as a special business by itself.

Travellers.—In order to raise heavy blocks of stone, etc., and place them in position, a *traveller* or travelling platform (Fig. 73), may be made to run on a raised tramway, called a *gantry* or *gantree,* formed by laying rails along the top of two parallel beams supported on two rows of standards, on opposite sides of the building, so as, if possible, to span the whole site of the work.

The traveller usually consists of two iron, or wooden, trussed girders, fixed parallel to each other, 3 or more feet apart; along the top of which a four-wheeled truck runs on rails, carrying a

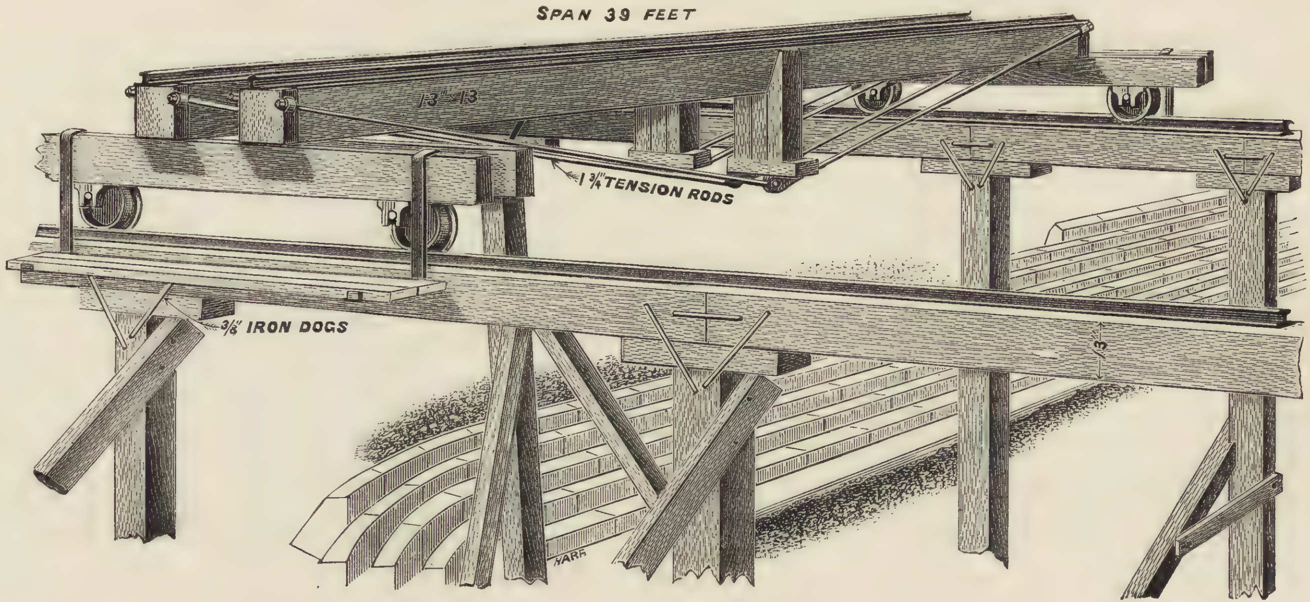


Fig. 73

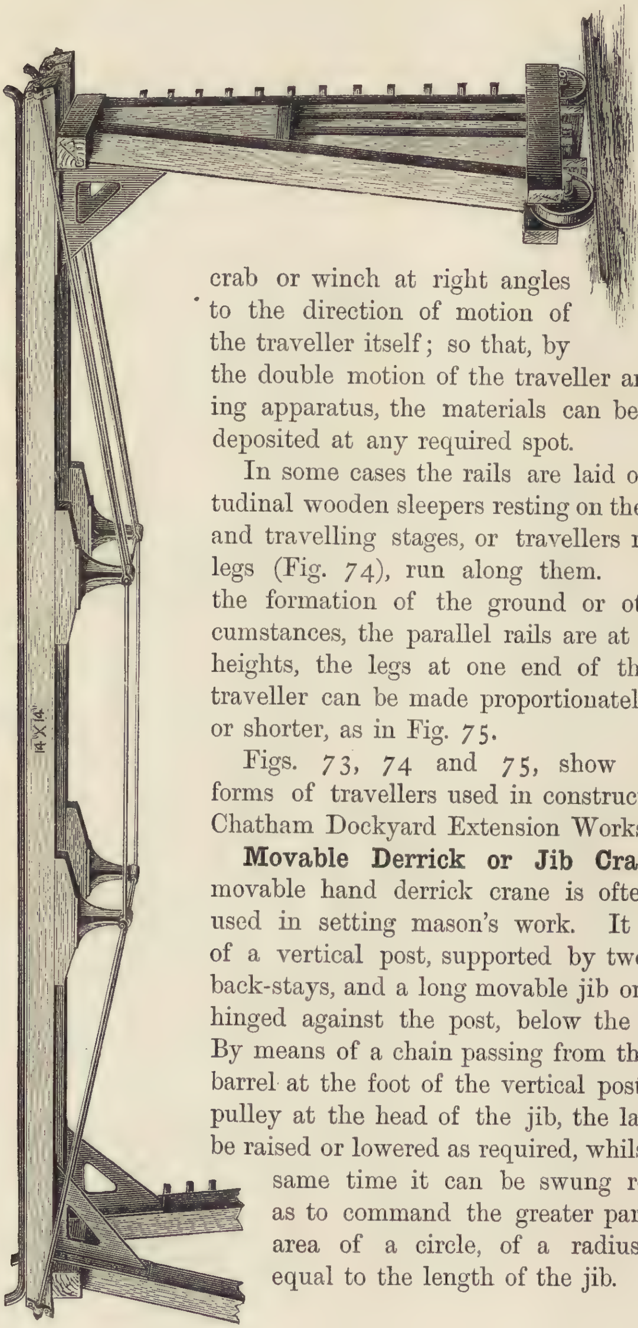


Fig. 74.

crab or winch at right angles to the direction of motion of the traveller itself; so that, by the double motion of the traveller and hoisting apparatus, the materials can be rapidly deposited at any required spot.

In some cases the rails are laid on longitudinal wooden sleepers resting on the ground, and travelling stages, or travellers raised on legs (Fig. 74), run along them. If, from the formation of the ground or other circumstances, the parallel rails are at different heights, the legs at one end of the raised traveller can be made proportionately longer or shorter, as in Fig. 75.

Figs. 73, 74 and 75, show different forms of travellers used in constructing the Chatham Dockyard Extension Works.

Movable Derrick or Jib Crane.—A movable hand derrick crane is often much used in setting mason's work. It consists of a vertical post, supported by two timber back-stays, and a long movable jib or derrick hinged against the post, below the gearing. By means of a chain passing from the lifting barrel at the foot of the vertical post, over a pulley at the head of the jib, the latter can be raised or lowered as required, whilst at the same time it can be swung round so as to command the greater part of the area of a circle, of a radius nearly equal to the length of the jib.

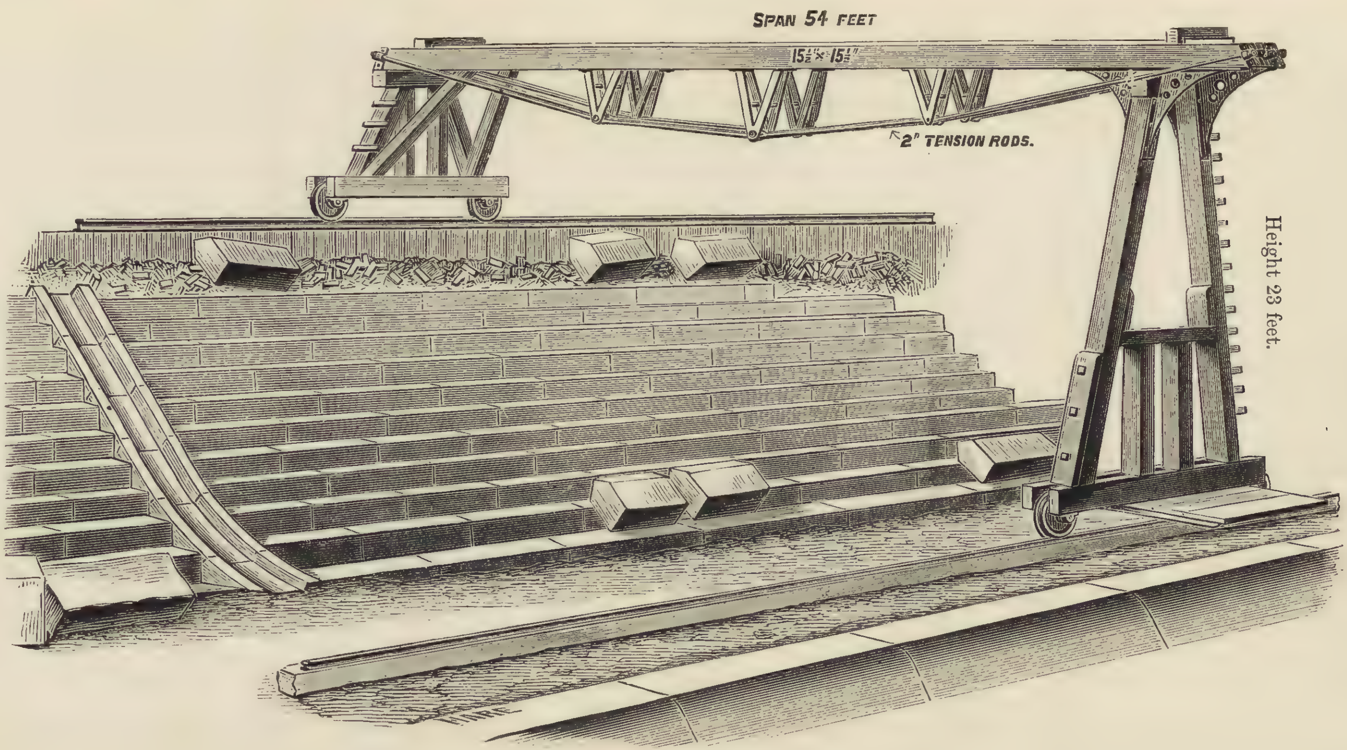


Fig. 75.

For sketches and prices of travellers, cranes, etc., see Appleby's *Handbook of Machinery;* Bolling and Lowe's *Price Book,* etc.

Holders for Stones.—There are various ways of laying hold of stones which are too heavy to be moved by hand. The following are those most frequently used:—

Nippers.—A pair of nippers or iron claws or hooks, as in Fig. 76, the ends of which catch in holes or on knobs, one in each side of the block, in the same vertical plane as, and at a convenient distance above, the centre of gravity of the block.

Single Plug.—A single iron plug very slightly tapered, and driven into a cylindrical hole directly over the centre of gravity

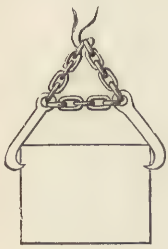


Fig. 76.

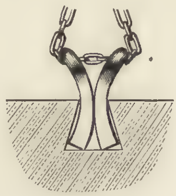


Fig. 77.

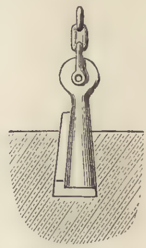


Fig. 78.

of the stone. By this simple means hard stones such as granite may be lifted with ease, a few side taps being sufficient to loosen the plug, when required to be withdrawn.

Double Plug.—Two curved iron plugs, with a chain passing through eyes in their heads, placed in a dovetailed hole, directly over the centre of gravity of the stone, as shown in Fig. 77.

Plug and Wedge.—An iron conical plug with an eye at the top, for a chain or hook to pass through, placed in a rather larger conical hole, directly over the centre of gravity of the stone, with an iron key piece—curved so as to fit the plug and the circumference of the hole—slipped in by its side, as in Fig. 78. This plug was used for setting the heavy granite coping on the Thames Embankment wall.

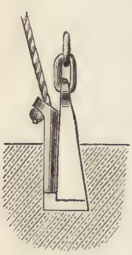


Fig. 79.

The plug may be rectangular instead of round, as shown on Fig. 79; and in laying blocks under water can be released, from the surface, by first drawing the side key by means of a cord attached to its head.

Lewis.—A *lewis* or iron dovetail, as in Fig. 80, made in three pieces; the two outer pieces *a a*, being first dropped into a corresponding dovetailed hole cut in the stone, directly over its centre of gravity, then the centre piece slipped in between them, the suspending tackle put in its place, and finally a bolt passed through the whole and keyed up.

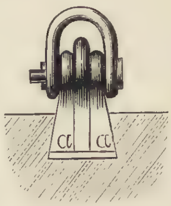


Fig. 80.

Principles of Stone-Laying.—The following observations apply to masonry constructions of every description:—

Bedding Stones.—All stones, except under peculiar circumstances, should be laid on their *natural* or *quarry beds*, or with their natural beds as far as possible perpendicular to the pressure they have to bear.

The strength and durability of the stone depends on this being done—even in cases, such as Bath stone, in which the natural beds cannot be distinguished by an unpractised eye—for few stones will bear the same pressure applied in the direction of their lines of stratification as at right angles to them; moreover, if the bed of a stone is exposed on the face of a wall, the water will get in between its layers, and frost will soon cause layer after layer to peel off; hence it follows that in projecting undercut mouldings and weathered copings, the natural beds should be placed parallel to the side-joints.

Bond in Masonry.—The careful bonding of the masonry must be attended to. A wall built of the roughest stones ought to be perfectly stable, though no mortar is used.

The principles of bond, by the stones overlapping and breaking joint throughout the wall, are the same as in brickwork, and should be thoroughly understood by the mason, for upon their skilful application his reputation as a good *waller* depends.

Wetting Stones.—All dry and porous stones should be well wetted before being laid in mortar, so as not to absorb the moisture required for the proper setting of the mortar.

Joints of Masonry.—All joints should be filled up solid with mortar.

The thickness of the bed-joints, depending on the smoothness of the beds, must be sufficient to prevent any unequal bearing resulting from actual contact between any irregularities on them.

Stains on Stones.—Where a good appearance is aimed at, all

stones exposed to view should be selected free from stains, chiefly caused by oxides of iron.

Iron in Stonework.—Iron should never be placed in contact with stonework where, by rusting, it might disfigure it with stains, or split the stone by its increase in bulk during the process of oxidation, or by its expanding and contracting under the influence of heat and cold.

Different kinds of Masonry.—In order to understand the practical operations of building in stone, it is necessary to explain the different descriptions of masonry in ordinary use. These may all be included under one of the three following heads, viz. :—

Rubble.
Block-in-Course.
Ashlar.

If the stone at disposal is thinly bedded, rough or intractable, it should be used as *rubble-work ;* if obtainable in blocks, and more or less easily wrought, it should be used as *block-in-course* or *ashlar*, according to circumstances.

Rubble Masonry.

In *rubble-work* stones of irregular size and shape are laid in a wall, after having been more or less assorted, roughly shaped to fit one against another, and hammer dressed on their faces with the waller's hammer, according to the quality of the work required.

In the rougher kinds of rubble-work no selecting of the stones takes place, but the waller, having once taken one up, places it in the wall as it will lie best, packing in smaller stones between the larger ones. The stones should be placed on their best beds, and not on their points, which would be liable to crush, in addition to the wedge-like action of such stones in the interior of a wall tending to dislodge the facework. No attention whatever is paid to the joints being more horizontal or vertical than naturally results from the bedding and cleavage of the stone used, upon which the degree of regularity in the appearance of the work mainly depends.

In rubble masonry the rough nature of the work leaves many spaces between the joints, both on the face and interior of the wall; these should be carefully packed up or *pinned* with *spalls ;*

which are the pieces knocked off the rougher stones, in order to get them to fit into place.

Care should be taken that the *hearting* or interior of a rubble wall is well packed with spalls and mortar, and not left full of hollows or mortar alone; to ascertain whether this has been done, take the waller's trowel and plunge it in different places into the heart of the wall.

The spalls must not be placed in the heart of the wall so as to drive like wedges when the weight from above comes on them, or the facing stones will be forced out.

Attention is necessary during the building of rubble, as well as all masonry walls, to insure their being well bonded transversely, and not built up with two thin scales on each face, tied together by *through* stones, with the core or hearting merely filled in with small pieces. This is a very common fault with masons, who will rely upon the mortar to give stability to a wall which, without it, would fall to pieces under its own weight.

The best stones for rubble masonry are those that scabble freely, and such as lie in 4 or 5 inch beds. Basalts and stones of a crystalline structure are troublesome to use, as they fly under the hammer, but granite and sandstones work in well.

Rubble may be either *uncoursed*—*irregular* or *random coursed*—*worked up to courses*—or *coursed*—chiefly depending upon the character of the stone at disposal. Some stones, such as Kentish rag, from their intractable nature, and the absence of any distinct lines of bedding, are specially adapted for *uncoursed* rubble; whilst others readily work into courses, and therefore should be used as *coursed* rubble.

Uncoursed Rubble.—In *uncoursed, random, rough,* or *common rubble* (Fig. 81) the stones are laid at random—without being brought up to any level courses—the only tools required being a trowel, waller's hammer, and plumb or battering rules, as the case may require.

Fig. 81.—Common Rough Uncoursed or Random Rubble.

One bond stone should be used to at least every yard super of the face, and they should run about $\frac{2}{3}$ to $\frac{3}{4}$ through the wall, alternately from the opposite sides; this,

in the case of dwelling-houses, diminishes the chances of damp being transmitted to the interior, and is in all cases much preferable to a smaller number of *through* stones, though in boundary and similar walls, *through* stones are more generally used. In thick walls, such as piers, abutments, and retaining walls, the bond stones should tail into the work as far as possible, and the whole should be bonded together in the best way the sizes of the blocks will admit of.

It is necessary to see the bond stones actually built into the wall, for builders are apt to set large stones on edge, running only 3 or 4 inches into the wall, instead of true bond stones—a trick which cannot well be detected after they have once been covered up.

Flint or river pebbles, or *popples* as they are sometimes called, are often used for this class of work, either laid in their natural forms or *polled*, that is, split, and their fractured surfaces shown on the face of the work, by which means a smoother and more finished face is obtained, and the rain can run down with less chance of getting into the body of the work. When walls are built up of such materials, brickwork, or masonry of a more regular description, should be used at the quoins or angles, and a few horizontal courses or bands of the same should, at vertical intervals, run through the whole thickness of the wall, to assist in tying it all together.

There is a superior description of uncoursed rubble much used

Fig. 82.—Random Rubble with Hammer-Dressed Joints and no Spalls on Face.

in ecclesiastical achitecture, which generally goes by the name of *rustic* or *random work*, in which no spalls should be seen on the face of the wall, and no horizontal or vertical joints are to be found. The stone employed for this class of masonry, such as

Kentish rag, being highly unstratified, cleaves into irregular shaped blocks which are fitted closely together (Fig. 82). Thus, in order to get A (Fig. 83) into place, the angles *a b c*, *d c b*, are

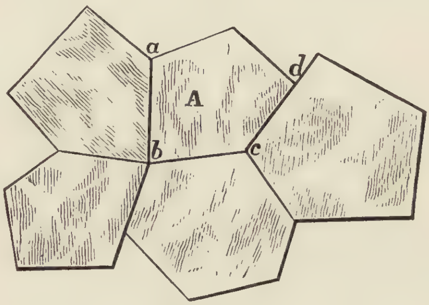


Fig. 83.

taken with the mason's bevel, and the joints are hammered and punched to fit truly. This is the most expensive kind of rubble-work, and requires much more skill to build properly than any other class of rubble-walling.

Irregular coursed Rubble.—If the rubble stone is distinctly bedded, the beds varying much in depth, and often running very thin, the stones should be put together, as in Fig. 84, in what is

Fig. 84.—Irregular Coursed, Random Coursed, Snecked or Squared Rubble.

called by architects *irregular* or *random coursed rubble*, and generally *snecked* or *squared rubble* by engineers.

In irregular coursed rubble the stones are bedded flat, and run to a certain extent in courses, which are, however, stopped at irregular intervals, just as any deeper stones happen to break them. The joints in this case are not necessarily vertical, but in a

superior class of the same work all the joints are specified to be vertical and the beds horizontal, by which the more regular appearance of squared rubble is obtained. The stones are all shaped, roughly squared if required, and hammer or axe faced, in the gross, ready for the waller to set in the wall.

This class of masonry is very bold and effective, especially for engineering purposes, when roughly squared and hammer dressed on face, and built up with a good proportion of large stones.

Rubble worked up to Courses—Coursed header Work.—Both of the kinds of rubble masonry just described are very commonly worked up at intervals, with the line and level, to level

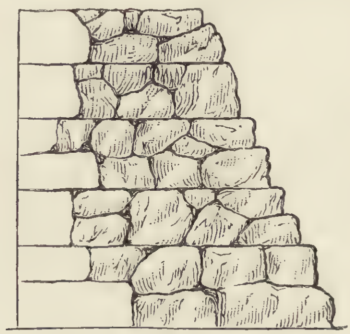


Fig. 85.—Common Rubble built up to Courses.

courses either regular or irregular in depth, the latter being both preferable on account of its appearance, and more suitable to the irregular sizes of the stone used. From 18 to 14 inches are the ordinary depths of the courses according to the nature of the stone. The *quoins*, or angle stones, whether of cut stone or not, are laid with care and accuracy, to serve as gauges to level the courses up to by means of lines and pins.

Such work is applicable to most kinds of building stones, so long as they are roughly bedded or easily cleft, as may be seen by looking at Figs. 85 and 86, which show both common and irregular coursed rubble worked up to courses; the latter being also called *coursed header work*, when the headers, occurring at intervals, run the full depth of the course. Fig. 86 is a superior class of work, the joints being vertical and beds horizontal, by which means a more regular appearance is obtained.

Rankine's *Civil Engineering*, p. 386, speaking of coursed header work says: "*One-fourth part* at least of the face in each course

should consist of bond stones or headers; each header to be of the entire depth of the course, of a breadth ranging from one and a half times to double that depth, and of a length extending into the building to from three to five times that depth, as in ashlar. Those headers should be roughly squared with the hammer, and their beds hammer dressed to approximate planes; and care should be taken not to place the headers of successive courses above each other, for that arrangement would cause a deficiency of bond in the intermediate parts of the course. Between the headers, each course is to be built of smaller stones, of which there may be one, two, or more, in the depth

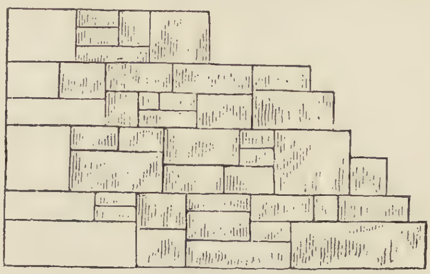


Fig. 86.—Squared Rubble built up to Courses.

of the course. These are sometimes roughly squared, so as to have vertical side-joints; sometimes the stones are taken as they come, so that the side-joints are irregular; but no side-joint should form an angle with a bed-joint sharper than 60°. Care should be taken not only that each stone shall rest on its natural bed, but that the sides parallel to that natural bed shall be the largest, so that the stone may be flat, and not be set on edge or on end. Howsoever small and irregular the stones may be, care should be taken to make the courses break joint. Hollows between the larger stones should be carefully filled with smaller stones, completely embedded in mortar."

The same authority gives the resistance of good coursed rubble masonry to crushing at about four-tenths of that of single blocks of the stone it is built with.

Regular coursed Rubble.—*Coursed*, or *regular coursed rubble*, as shown in Fig. 87, is applicable where the beds, though thin, are pretty regular, so that a sufficient number of stones of a uniform depth can be got to allow of their being laid in regular courses of one stone only in depth.

Dry Rubble Walling.—Dry walling is the simplest class of rubble-work, and consists of stones roughly hammered, and bedded by pinning with spalls, without any mortar. It requires consider-

Fig. 87.—Coursed Rubble.

able skill to build properly, as its stability depends entirely on the firm bedding and bonding of the different stones. It is chiefly used for fencing land, railway and canal embankments and cuttings; or at the backs of retaining walls to diminish the pressure of the earth on them, and to allow of water finding its way down to the drains below. When used for fencing such walls are generally about 5 feet high, increasing in thickness towards the bottom, and averaging about 18 inches in thickness

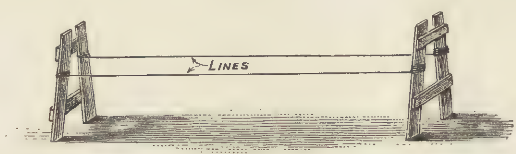


Fig. 88.

and are usually built to lines strained between trestles (Fig. 88) in order to avoid plumbing the face.

Dry rubble walling is generally built in courses about 12 inches high, and should have a waterproof top, or *coping*, to keep the water from getting into the body of the work and bursting it in frosty weather. The coping may be made of stones laid on edge in mortar (Fig. 89), of bituminous concrete, or, for want of anything better, clay puddle, or even sods.

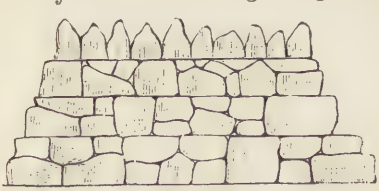


Fig. 89.

When the stones come out in thin slabs, the walls may be specified to be built of "good, sound, flat bedded stones of a fair average size (none less than 6 inches broad across the narrowest part), set dry, and coped with stones, not less than 9 inches deep, set on edge; each coping stone to extend across the full breadth of the wall, and to be properly set in good hydraulic mortar."

Dry walling is sometimes *lipped* and *rough-casted*, which consists in dashing mortar into the open joints with an ordinary trowel, and then splashing the whole face of the wall with *rough-cast*, a coarse liquid mortar made of *hot* lime, sand, and grit or fine clean gravel; a wood trowel, or even a bullock's hoof being used for the purpose. This greatly preserves the stone from the disintegrating effects of the weather.

Joints of Rubble Masonry.—A *high joint*, with a projecting ledge, is what is very frequently used to mark the joints of rubble-work; it is a bad system, and, as explained (pp. 50-53), is sure to peel off under the influence of wet and frost.

A *flush* or *flat* joint, which may be *jointed* or lined down the centre, is a good joint to use. Sometimes a round piece of iron is pressed into the flat joints while the mortar is still soft. The best joint is the *mason's joint*, as shown at *e*, Fig. 25, or a struck joint as at *c*, well struck back at the top edge of the horizontal joints, so as to allow the rain to run off freely; a good effect is also produced, owing to the shadow of the projecting edge of the stone above emphasising the joint below.

Galleting is a method of marking the coarse joints of rubble masonry, in which small chips of flint, etc., are stuck into the mortar while still soft, generally crossing the joint diagonally; it often has a pleasing appearance, but is open to the objection of catching the rain. Fine gravelly pebbles may also be pressed into flush joints while the mortar is still soft.

The rougher the class of work, the more mortar is required in bedding the stones. A cubic yard of rubble masonry will, as a rule, require $\frac{1}{5}$ cubic yard of mortar, and $1\frac{1}{5}$ cubic yard of stone.

Quoins to Rubble Walling.—Larger stones, either selected blocks of rubble, or often of cut stone, equal in depth to two or three courses of the rubble walling, are generally used at the quoins.

Whenever cut stone is used in connection with rubble-work, as at the quoins of a building, the ends adjoining or tailing into the rubble should never be cut square but left comparatively

rough, as shown in Fig. 85, so as to harmonise with the masonry in the body of the wall, and not appear as if cut off from it by strong lines of demarcation.

Block-in-Course Masonry.

Block-in-course (Fig. 90) is a term applied by engineers to a class of masonry much used in piers, abutments, wing walls, etc.,

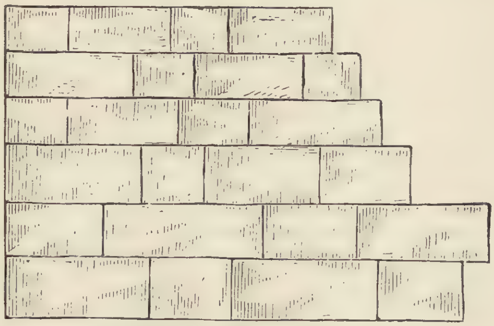


Fig. 90.—Block in Course.

when there is a suitable stone in the district, and good solid work is required. The stones are all squared and brought to good fair joints, the faces being more or less worked, according to taste, but generally merely hammer-dressed; and the courses consist of single stones only in depth. It chiefly differs from ashlar in the smaller size of the stones and depth of the courses; the stones at command being ordinarily rougher and more thinly bedded—chiefly *shoddies* or stones under 12 inches deep, whereas *ashlar* blocks range, as a rule, from 12 to 14 inches in depth.

The best stone for the purpose is a hard self-bedded stone, which will work easily into courses from 3 to 10 or 12 inches in depth, the length of each stone being four or five times its depth. No attention is paid to uniformity in the depth of the courses. The quoins, or angle stones, may be formed of the larger blocks, equal in depth to two or even three courses of the body of the work, though, in superior work, cut stone quoins are used.

According to the amount of labour bestowed upon block-in-course work, and the size of the stones employed, it may approximate more or less closely to coursed rubble on the one hand, and

on the other to the regularity and finish of that class of masonry known as *Ashlar.*

Ashlar Work.

The term *Ashlar* is applied to masonry built up of a thick bedded stone which admits of being scabbled or sawn into squared blocks of given dimensions. It is also used to denote roughly-squared blocks of stone, over 12 inches deep, as delivered from the quarry or stonecutter, or as prepared for setting.

Ashlar work (Fig. 91) is built in courses of more or less uniform depth—generally from 10 to 14 inches—ranging

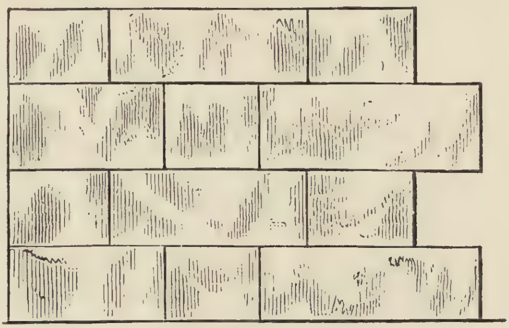


Fig. 91.—Ashlar.

throughout with the quoins and dressings; it goes by different names, according to the face put upon the stone—from *quarry-pitched* or *rock ashlar* up to *wrought ashlar.*

No stone should be laid in mortar without being first fitted into place, and any irregularities in shape corrected. Large ashlars are first accurately fitted into place, and then set on a bed of mortar carefully spread out to receive them, after which the vertical joints have to be filled by stopping them up on the outsides with cement or mortar, and pouring in cement or mortar grout, which should be worked about with a piece of hoop-iron, so as to insure its completely filling the joints.

The beds and joints are worked to plane surfaces, so as to allow of close-fitting joints. These surfaces should not be too smooth, otherwise the mortar will not adhere so well to the stones, but in good work should be true enough to allow of joints not over $\frac{1}{8}$-inch thick; they are generally either left as they came from the saw (if sufficiently true), or taken out of winding

by running chisel draughts round the margins, and dressing them down with the point, as in half-plain work, taking off with a chisel any parts left projecting beyond the level of the chisel draughts.

Even should the facework be only quarry-pitched, chisel draughts must be run round the face of each stone, in order to insure truly-square arrises and close-fitting joints. Ashlar walling is, however, generally wrought or dressed to a finer face, such as tooled, rubbed, or polished.

Brick and Rubble Ashlar.—As it would be too costly in these days to build thick walls entirely of squared stones laid in regular

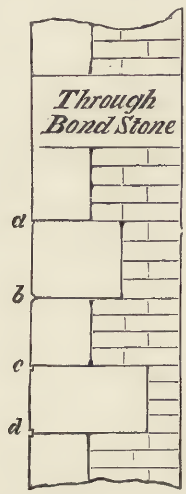


Fig. 92.—Brick Ashlar.

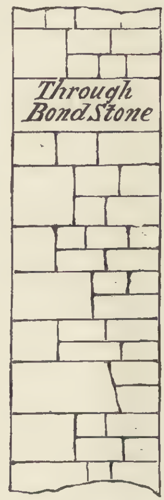


Fig. 93.—Rubble Ashlar.

courses, ashlar work is usually employed in the dressings only of walls, or, at the most, for facing such parts as are exposed to view, the rest being built up in a less expensive way, of rubble masonry or brickwork, as in Figs. 92, 93; hence it is necessary that great attention should be paid to the proper bonding of the facework to the body of the wall, in order to guard against their separating from each other, a result which frequently happens when sufficient care is not taken. For this reason the backing should always be built in courses, carefully levelled up to coincide with the courses of ashlar; that being the best work in which the number and thickness of the bed-joints in the face and back of the wall agree most closely, so as to allow of equal settlement throughout. Consequently, a brick backing is not good, unless cement or a quick-

setting mortar is used to prevent the joints from yielding under pressure; though where bricks are cheap, and economy is necessary, it has the advantage, where plaster is used, of admitting of its direct application, whereas a rubble wall has generally to be lined with battens and laths to carry the plaster.

In facing walls, either with block-in-course or ashlar, no stone should have a bearing area on bed less than the area of its face, in order to insure stability, and prevent undue pressure causing the outer edges to spall or split off.

The proportion and length of the headers should be the same as laid down below, the beds and joints being squared to a depth of not less than from once to twice the depth of the course. Their tails may be left rough at the back and sides, so as to work in well with the rubble backing, but they should not diminish in depth from face to tail.

This mode of building is so general in England, wherever stone is employed for building purposes, that an *ashlar wall* is very generally taken to mean a wall only faced with ashlar; the term *brick ashlar* being applied to brick walls faced with ashlar masonry. It is not, at the best, a mode of construction to be recommended, as the bonding between the face and body of the work can never be perfect, and unless strong hydraulic lime or cement is used unequal settlement is always liable to take place, from the greater number and thickness of the joints in the body of the wall, more especially if the work is rapidly executed. In bad work of this description, which is the rule rather than the exception, the facing is often nothing but a veneering of thin slabs of stone, not more than 4 or 5 inches thick on bed, tied in here and there to the body of the wall; the bulging of the face-work often betraying the secret of its construction.

Throndes, or headers the full thickness of the walls, should never be allowed in walls of houses as they transmit damp.

Proportions for Stones.—In both block-in-course and ashlar masonry it is necessary to proportion the length, breadth, and thickness of the stones according to their hardness, in order to guard against their breaking across. Thus (Rankine's *C. Eg.*, par. 242) in the weaker sandstones and granular limestones the length of a stone should not exceed three times its depth, nor the breadth one and a half to double its depth. In harder stones—such as require $2\frac{1}{2}$ or more tons to the inch to crush them—the length may be four or five times, and the breadth three times the depth.

Bond.—The best bond in masonry is that which shows on the face of the work alternate headers and stretchers in each course, as in Flemish bond in brickwork, each header coming over the centre of a stretcher in the course below. In such work one-third of the face consists of headers, if the length of the stretchers is twice the breadth of the headers; but as stones are rarely cut to exactly the same dimensions, it may be laid down that not less than one-fourth of the face of the wall should consist of headers, and that the stones should break joint from once to one and a half times the depth of the course.

JOINTS.—The thickness of the joints will vary from $\frac{1}{2}$ to $\frac{1}{8}$ of an inch, according to the smoothness of, or amount of work bestowed upon, the beds, as it must be sufficient to transmit the pressures from stone to stone, without permitting of actual contact at any point of their surfaces. The mason's joint, already described on page 51, or a properly struck joint, is the best which can be used.

Flush Joints.—Care should be taken to prevent the use of *flush* joints, which are formed by hollowing the beds below the plane of the chisel draughts run round the edges. This was sometimes done by the Greeks, in order to get perfectly close joints; but, by throwing all the pressure on the edges of the stones, they frequently splinter off and spoil the look of the work.

As flush joints cannot be detected after the stones are laid, the masons must be well looked after while at work upon them.

With a view of guarding against the splintering or *spalling* of the arrises of cut stonework, as in columns carrying heavy weights, 7 or 8 lb. sheet-lead is frequently placed between the stones. The lead, which is not allowed to reach to within less than 1 inch of the edges of the stones, is thought to equalise the pressure over the beds by yielding to any slight irregularities on them; however, experiments made by Mr. Kirkaldy have shown that the use of lead instead of mortar is a great mistake. He found that stones bedded on thin pieces of pine, instead of lead, equal in area to the bed-joint, bore a greater crushing force than stones double their sectional area bedded on lead in the usual way. The lead which had been used showed no signs of accommodating itself to the irregularities of the beds.

The joints of stone columns are often raked out about 1 inch deep, and pointed up when there is no longer any fear of their

settling. The arrises of stones are also prevented from spalling by cutting them back, as at *a*, *b*, and *c*, Fig. 92, though this is generally done merely to give a bolder effect to certain parts, such as the quoins and lower stones of buildings.

Open Joints.—Open joints, resulting from projections beyond the plane of the chisel draughts, must also be avoided, especially in the beds, as tending to distribute the pressure unequally over them.

Rusticated Joints.—Rustic work, as already stated, properly applies to facework left rough from the hammer, though it also applies to a debased class of masonry, picked into deep holes, or honeycombed all over, to give a rough effect; but the term rustication, or rusticated, is also much used to denote masonry in which the joints are either chamfered, as at *a* and *b*, Fig. 92, or sunk square below the facework, as at *c* and *d*.

Saddled or Water-Joints.—In addition to the sloping off or weathering of the upper surfaces of stonework exposed to the rain, as in copings, cornices, and string courses, it is well to *saddle* the joints, by leaving them rather higher than the rest of the work, as in Fig. 94, in order to throw the rain away from the joints, and so prevent any water finding its way through them, and down the face of the work. Such joints are also called *water-joints.*

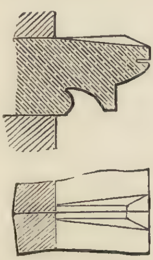


Fig. 94.—Saddled Joint.

Rebating.—The adhesion of mortar or cement, and the weight of the stones themselves, cannot always be relied upon as affording sufficient stability to stonework, especially when not built into the body of the work, where they would be held in place by the superincumbent weight; hence different methods are resorted to in order to give additional stability, such as *rebates, joggles, cramps, lead plugs,* etc.

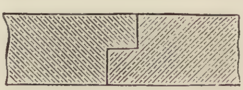


Fig. 95.—Rebated Joint.

A rebated or lap joint (Fig. 95) is formed by cutting away a portion of the edge of each stone, so as to allow them to lap over each other. Fig. 96 shows the proper way of making a rebated joint on a slope, as in the case of a barge course or coping on the gable end of a building; water is thus effectually kept out, which would not be the case if the side *a* were uppermost.

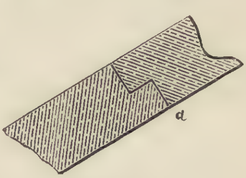


Fig. 96.

Joggling.—Stones are said to be joggled

together when prevented from sliding by a projection or *he-joggle*, on one stone, fitting into a corresponding notch, or *she-joggle*, in the other stone (Fig. 97).

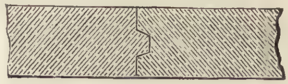


Fig. 97.—Joggle Joint.

The he-joggle is generally cut square, and should taper slightly from the shoulder to the end, being stronger and easier to cut and fit into place when so made. If, instead of one or more square joggles, the joggling is continued along the joint, it becomes a *tongued* and *grooved joint*.

Dowelling.—The above methods, except in special cases, as in Fig. 96, are wasteful both of labour and material; a better plan, therefore, is to sink, exactly opposite each other, two she-joggles or *dowel holes*, one in each stone, either circular or square in section, and fit into them a *dowel* or pin (Fig. 98), either of some hard stone, such as greenstone, granite or slate, or of brass, zinc, or copper.

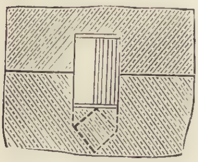


Fig. 98.—Dowel.

Copper dowels are the best, but very expensive; iron are the strongest, but should not be used unless perfectly secured from air and moisture, for fear of their cracking the stone during the process of oxidising, and as an additional precaution they should be thoroughly tinned or galvanised.

There is nothing, perhaps, better, on the whole, than good hard slate dowels run with brimstone or cement.

Where very perfect workmanship is required, as well as when placed so as not to admit of being run in, the pins are made to fit the dowel holes accurately, being slightly tapered towards the ends, to secure a good fit, and facilitate the setting of the stones.

Cramps.—Iron or copper cramps (Fig. 99) are used to connect stones together. Two holes are sunk opposite each other on the surface of each stone, within a given distance of the joint, with a channel connecting the two, which should be deep enough to allow of the cramp being completely protected from the weather by lead or cement, as the case may be. They are generally *run* with lead, and the returned ends jagged to give a better hold to the lead.

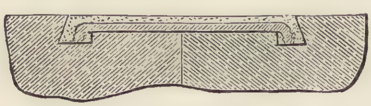


Fig. 99.—Metal Clamp.

Cramps are unsightly and not to be relied on; whilst, if of

iron, any flaw in their covering may turn them into agents of destruction.

Lead Plugs.—In connecting stones by means of lead, plug holes, which may be dovetailed if thought necessary, are made, one in each stone, exactly opposite each other, as in Fig. 100, with a channel leading to them from the top of the joint, through which molten lead is run into them. The bottom of the plug holes should slope downwards, so as to carry the lead into them at once, as well as to give the stone a more secure hold of the lead. Great care should be taken in running in lead that there is no moisture in the holes, which, if suddenly converted into steam, might cause a serious accident.

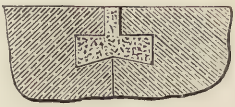


Fig. 100.—Lead Plug.

Dovetail Bonding.—In masonry constructions intended to resist the shocks of waves, in addition to the methods given above, the stones may be held in position by being dovetailed one into the other (Fig. 101), as was done by Smeaton at the Eddystone lighthouse; but good cement and dowels would no doubt be equally efficacious, and at the same time less expensive.

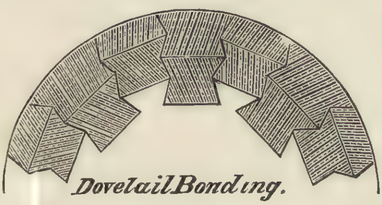


Fig. 101.

Tabling.—Stones of different courses may also be given great resistance to lateral shocks by *tabling* (Fig. 102), in which a flat projection cut on the bed of one stone fits into a corresponding sinking in the bed of the one under or overlying it. This method, however, is wasteful both of material and labour.

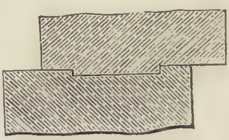


Fig. 102.—Tabling.

Securing Bolts, etc., in Stonework.—Iron bars and bolts are generally secured in stonework by being enlarged or jagged at the ends—bolts so made are called *rag-bolts*—let into dovetailed holes in the stone, and run with lead, Fig. 102a. Brimstone is often preferred to lead, being cheaper and less liable to loosen by expansion and contraction; it was used for securing the bed-plate bolts which support the Crumlin Viaduct girders.

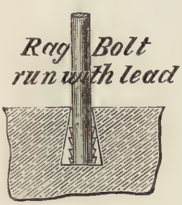


Fig. 102a.

PROTECTING CUT STONEWORK.—Any projecting or carved stonework in a building should be boxed up with rough boarding, after it has been set, to guard against its being injured by the carelessness of workmen, or by bricks, etc., falling from the scaffolding, during the progress of the work. The treads and nosings of steps should also be boarded over for the same reason, as well as to protect them from the rough traffic.

All the cut stonework should be well pointed and cleaned down before the building is given over for use.

MEASUREMENT AND VALUATION OF MASONRY.

WALLING.—In districts where stone abounds and forms the principal material for building purposes ordinary walls are built of rubble-stone, and measured by the cubic yard or some other local standard, such as, in Ireland, by the running perch (21 feet) of a given height and thickness, or by the square perch of 21 feet super, at a standard thickness of 18 inches. In the west of England the square perch is employed, of 18 feet super, at a standard thickness of 2 feet, to which walls of any thickness are reduced; or the price per perch may vary with the thickness of the wall. In other parts masonry walling is measured by the rod of 36 square yards or 24 cubic yards, the standard thickness being 2 feet; or by the rod of 272 feet super, as in brickwork, at a standard thickness of 18 inches or 2 feet.

In engineering, as distinct from architectural constructions, masonry is rarely valued otherwise than by the cubic yard for the roughest description of work, and by the cubic foot for superior work.

The price in all cases varies with the quality and description of work, as "coursed" or "uncoursed," in "walling" or "foundations;" also, upon the thickness of the walls, for it must be borne in mind that the cheapest walling is that to which the nature of the stone most readily adapts itself. Thus, in many stone countries walls 2 feet thick are less costly than if only 18 or 20 inches thick, as the saving in material does not make up for the extra labour involved in adapting the stones to the reduced thickness of walling.

The superficial content of the surface-work is paid for separately by the square foot, yard, or rod of 36 square yards, including jointing or pointing, and such squaring to beds and joints as may

be required; quoins, etc., of selected stones being often paid for at so much extra per foot run.

Superior work, such as squared masonry, whether in walling or dressings, is usually valued by the foot cube as block stone, merely scabbled or sawn to the required dimensions, and set. The work upon it is taken separately by the foot super, as described for cut stonework below.

When different descriptions of masonry occur in a wall, such as rubble faced with ashlar, instead of cubing out the rubble and ashlar work separately—in which case the latter is valued by the cubic foot prepared and set, including all beds and joints, the facework being taken by the foot super, as tooled, or as the case may be—the whole may be taken as rubble masonry, and so much extra allowed per foot super for the superior facing, including all extra labour, dressing, and pointing.

When walls are built of rubble masonry, it is invariably cheaper to buy bricks at 30 or 40 shillings per 1000, and build them into such parts as jambs and arches, than to work the stone to given forms; and this would hold good even in internal jambs and arches, the labour upon which would be much less than in those shown on the face of the wall.

The technical terms given to masonry being differently understood by builders in different districts, a specification should define clearly the exact class of work required, as the amount of hammer-dressing, spalling, etc., will make a vast difference in the cost of the work.

Samples of Masonry.—It is advisable, in works of importance, to have specimens of the required masonry built on the site of the proposed works, as standards for the masons to keep to. When work is to be put up to tender, such specimens are of great use in preventing any subsequent dispute with the contractor as to the real meaning of the wording of the specification; but great care should be taken not to make them of a higher standard than can be attained, on a large scale, on carrying out the work, without running into unnecessary expense. They should be fair average samples of the work which will be enforced, not specimens of perfect masonry.

Cut Stonework.—The block stone, for the cut stonework in a building, is ordinarily sold at the quarries, or delivered, by the cubic foot, or in large rough blocks by the ton of from 13 to 17 cubic feet, according to the description of the stone, 1 inch being allowed each way for irregularities and waste.

The following table, from Adcock's *Engineer's Pocket-book*, gives the quantity of stone of different kinds, equivalent to a ton in weight :—

	feet cube.	inches.		feet super.
Vein marble	13	$2\frac{1}{2}$	York paving	70
Statuary do.	$13\frac{1}{2}$	3	,,	58
Granite	$13\frac{1}{2}$	$2\frac{1}{2}$	Purbeck paving	68
Purbeck	14	3	,,	56
Yorkshire	$14\frac{1}{2}$ to 15	3	Granite	54
Craigleith	$14\frac{3}{4}$	6	,,	27
Portland	15 to 16	7	,, curb	23
Derby	15			
Bath	16 to 17			

Cost of Rough Stone.—Apart from the value of the stone itself, its price increases with the restrictions put upon the size and shape of the blocks required. The cost will be at a minimum when the stone is taken just as it comes out from the quarry and will vary as follows :—

1*st*. When one dimension, as the height of a course of ashlar, is fixed, the other dimensions being left, within certain limits, to the quarryman.

2*d*. When two dimensions are fixed, as the thickness and width of coping stones, the length being open.

3*d*. When all the dimensions are fixed.

4*th*. The cost will be less if not required to be scabbled square all round, as at the back of ashlar headers tailing into rubble work.

All cut stonework over 3 inches thick, such as steps, cornices, arch stones, etc., is first measured and valued by the foot cube, as stone in block, including setting up to 30 feet in height, for every 10 feet beyond which it is usual to charge extra for hoisting.

The dimensions of each stone should be taken as that of the smallest rectangular block from which it could be prepared, or if splayed or feather-edged (triangular in section) the smallest rectangular block from which two stones could be cut, allowing, though not by the War Department Schedules, an extra half-inch one way for waste in sawing. The width of bevelled stones, such as voussoirs, is often taken at $\frac{1}{6}$ above their mean width, to allow for waste.

Stones over 6 feet long must be cubed separately, as they are charged extra, and described as *scantling* lengths.

As a general rule, paving, landings, and cut stone finished to 3 inches thick or under, are paid for by the foot super; the

price per foot super increasing with the superficial content of the stone.

Common forms of copings, curbs, and window sills, etc., are sold by the foot run ready for setting.

Labour on Stone.—After cubing out the stone in block, the finished work upon the plane surfaces is measured out by the foot super, as hammer-dressing, half-plain work, plain work, tooled work, etc., already described under "Work on Stone," pp. 84, 85.

In order to ascertain the real value of the work upon a stone, it is necessary to understand every process through which the stone had to pass, such as what surfaces had to be dressed down to planes before the finished work could be put upon it; and some hold that the different kinds of work should be measured separately, just as they were put upon the stone; it is, however, much simpler if the ordinary method is pursued of fixing the price of the finished work, so as to include all the necessary preparation to receive it.

Sunk Work.—When part of the surface is sunk below the rest, as in cutting a chase, the radiating joints of stone voussoirs, or in the weathering to a coping or a window sill, it is measured as *sunk work*, the whole of the work sunk beneath the surface of

Fig. 103.

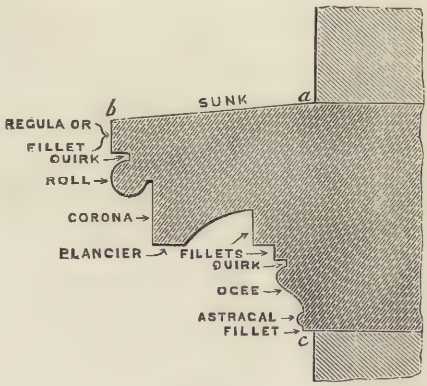


Fig. 104.

the stone being girt in the measurement (Fig. 103, and *a*, *b*, Fig. 104).

Circular Work—Circular circular Work—Circular sunk Work.—When the surface, instead of being a plane, is curved in one direction, it is called *circular* work, as in the case of the curved extrados and intrados of a stone arch ring; if curved both

on plan and section it is *circular circular* work, as in the outer and inner surfaces of a hollow stone dome; if curved in one direction only, but gradually sinking in a straight line, as the inner and outer surfaces of a hollow truncated semi-cone, or the face of a diminishing column, it is called *circular sunk* work, as is also sunk work carried round a curved surface.

Moulded Work—Circular moulded Work.—If a curve is irregular, as in an *ovolo* (Fig. 105), or changes direction, as in a

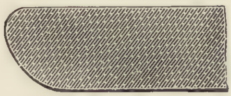


Fig. 105.—Ovolo.

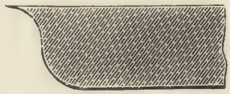


Fig. 106.—Reverse ogee or cyma recta.

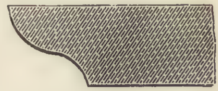


Fig. 107.—Ogee or cyma reversa.

cyma (Figs. 106 and 107), so named from the Greek for a wave; or if the profile line includes different members, it is termed *moulded* work, the feet super being arrived at by girthing the profile (Fig. 104, *b*, *c*). Moulded work carried along a curved surface, as round the capital of a column, is called *circular moulded* work.

Mitres, etc.—Stops to sunk Work.—When sunk work, circular work, or mouldings running in different directions, meet at an angle, the length of the line of intersection is girt by the inch or foot run, in order to pay for the extra labour involved. The angle so formed is termed an *internal* or an *external angle* or *mitre*, and is in many cases paid for at the price of a foot super of the intersecting surfaces. For the same reason, when sunk work etc. is not run through the whole length of a stone, as in the sills of windows, the line along which it is stopped is measured by the foot run, and paid for in the same way, under the head of *stops to sunk work*. This is the usual practice, though not always followed when measuring work to be paid for on the War Department Schedules.

Beds and Joints.—In the War Department Schedules the cube price of the stone is made to cover all beds and joints squared their whole depth, but the work on the beds and joints of each stone should be measured as *half-plain work*, a sawn face being taken as equivalent to half-plain work.

When the surfaces of two stones meeting, to form a bed or side joint, are equal in area, instead of taking each separately as half-plain work, it is customary to take them both together as *plain work;* and in order to save the trouble of counting the number

of plain joints in continuous members, such as cornices, copings, etc., one joint is usually allowed to every 3 feet in length.

When bevelled stones, such as voussoirs, have to be cut separately out of squared stones, the splayed joints should be measured as *sunk joints* or *rough sunk work* to joints; and similarly with any sunk work, where the labour is equivalent to half-plain sunk work.

Narrow Surfaces, etc.—Narrow surfaces, such as *throating, chamfering* under 3 inches wide, *rebating, grooving* under 4 inches wide, *beads, flutes, reeds, mitres,* and *stops* to sunk and moulded work, are paid for in the War Department Schedules by the foot run.

Letters, figures, mortise and *rail holes* over 1½ inch deep, *cramps,* etc., are paid for by the inch run; and small, isolated pieces of work, such as *mortise* or *rail holes* under 1½ inch deep, and *plug holes,* by the number.

The ordinary practice pursued in measuring different kinds of mason's work will be found in Hurst's *Handbook,* Kelly's *Price Book,* etc.

CONSTANTS OF LABOUR.—Constants of labour are most useful in setting task or piece-work, as well as in the valuation of work done. Rankine's *Rules and Tables,* pp. 253, 254, give a number of constants, mostly applicable to the practical operations of building in different kinds of masonry.

The following constants, chiefly for work on stone, are taken from the *Students' Practical Guide to Measuring,* by Dobson. The factor to be applied is the daily rate of wages for a mason :—

LABOUR ON PORTLAND, OR SIMILAR STONE, PER FOOT SUPERFICIAL.

N.B.—Sawing to be taken as half-plain work.

		Days.
Plain work to bond stones . .	per foot super. .	·140
„ to beds and joints . .	„ .	·181
„ rubbed face . . .	„ .	·209
„ „ circular . .	„ .	·291
Sunk work rubbed . . .	„ .	·250
„ „ circular . .	„ .	·313
Moulded work rubbed . . .	„ .	·292
„ „ circular .	„ .	·417
Circular work to shafts of columns having the neck moulding, or part of the base, worked in the same stone	„ .	·334

		Days.
Circular circular or spherical work to domes or balls . . .	per foot super. .	·500
If rubbed, add extra . . .	" .	·049
Labour, squaring and laying York or Purbeck paving . . .	" .	·021
If in courses, add	" .	·010
Taking up, squaring, and relaying old paving	" .	·042
Add if in courses	" .	·015

PAVIOR'S WORK.

The pavior's work consists of laying hard-wearing surfaces both indoors (as in stables, stores, and dwelling-houses) and out of doors (as for yards, footpaths, roads, etc.)

The only special tools used by the pavior are wooden beetles and other rammers for consolidating foundations and block or slab paving.

The materials used for paving are chiefly hard bricks of different kinds, such as paviors, blue Staffords, Dutch clinkers, adamantine clinkers, special grooved blocks of similar materials, stone slabs (both natural and artificial), pebbles, granite and other setts, wood blocks, asphalt (natural and artificial), tiles and mosaics of different kinds from the simplest to the most highly decorative.

All special kinds of paving, such as asphalt, wood block, mosaic, etc., should be laid by men specially trained to the work.

The success of every kind of paving depends on the foundations upon which it is laid being firm and unyielding; hence for heavy town traffic 9 inches of good Portland cement concrete, at least 1 to 8, should be adopted, the ground beneath being well rammed solid.

A first-class yard paving consists of 6 inches of Portland cement concrete (laid on a well-rammed foundation trimmed to the required falls) covered with 2 inches of coarse screened gravel and 4″ × 4″ × 5″ Mount Sorrell granite or other suitable setts, dressed on top and sides, the joints being filled up and brushed in with unscreened Mount Sorrell granite chippings, and the whole rammed solid. For stables an inch of coarse sand may take the place of the gravel, and the joints should be grouted in solid with 1 cement to 3 sand.

Much valuable information on "Pitched Pavements," "Wood Paving," "Compressed Asphalt Roadways," "Footpaths," "Kerbing and Channelling," etc., will be found in *The Municipal and Sanitary Engineer's Handbook*, by H. Percy Boulnois, C.E.

For the prices, etc., of pavior's work, see Laxton's, Kelly's, and other Builders' Price Books.

CHAPTER III.

CARPENTER'S WORK.

UNDER this head in the War Department Schedules are comprised Sawyer's, Carpenter's, and Joiner's Work, as well as the supply and fixing of ordinary articles included under the head of Upholstery and Ironmongery.

For the sake of clearness each description of work will be taken separately.

SAWYER.

The sawyer, as his name implies, saws timber into suitable scantlings for the use of the carpenter and joiner.

The labour expended in sawing being generally included in the cost of sawn timber, or in the charges made by the carpenter or joiner, is as a rule lost sight of, but as it forms a considerable item in the ultimate cost of all woodwork, the subject is one which must not be overlooked.

Before describing the actual work performed by the sawyer, it will be well to see how fir timber, which is the principal material he has to deal with, is imported into this country.

In London and all large ports timber is bought from the timber docks, where it is sold by brokers who act as agents for the shipper. Public sales of timber lying in the docks (the Surrey and Commercial are the principal docks in London for Baltic and Canadian timber) are continually being held; whilst purchases can at all times be made privately from any timber broker.

Fir timber for building purposes is mostly shipped in the rough to our ports as *square timber*, *deal*, and *poles* for scaffolding.

Square Timber.

After fir timber is felled, the soundest, longest, and most regular-shaped trees are generally, after being topped and barked, exported under the name of *hand masts;* the next best trees, at ports from which deals are shipped, are sawn into planks, deals, and battens, and the remaining logs are then hewn square, shipped in balk, and sold in the market as square timber. These balks are mostly squared with the axe at the felling grounds, but Memel and Dantzic fir and American pitch pine are often sawn die-square.

A great deal of valuable information connected with the different timber-producing trees, felling, seasoning, and strength of timber, is given in Hurst's Edition of *Tredgold.*

Baltic Fir.—Baltic fir, or red pine, balks (Scotch fir, or *Pinus sylvestris*) run from 11 to 18 inches, and even up to 21 inches square, averaging 13 inches square, and from 18 to 50 feet in length. All logs under 12 inches square are termed *undersized;* whilst logs 8 by 8 inches and under are distinguished as *balks.*

Red Fir or Northern Pine.—The best Baltic fir in balk comes from the Prussian ports of Memel, Dantzic, and Stettin, but chiefly from the two first. Memel timber runs in the most convenient sizes, not as a rule exceeding 13 inches square and 35 feet in length; whilst Dantzic is considered the strongest, when free from cup or ring shakes[1] and large knots, and averages from 13 to 16 inches square, and 30 to 45 feet in length. Longer timbers are apt to run knotty at the top ends.

Fir timber from Riga and other Russian ports, being less resinous, is softer and inferior in strength and durability to both Memel and Dantzic, and does not run so large, being mostly about 12 inches square and 40 feet in length, but is preferred by some on account of its being straighter grained and freer from bad knots, for which reason it is much used for masts of ships; it is, however, subject to heartshakes and starshakes,[2] besides which it is getting so scarce that there is no certainty about obtaining it.

Fir timber from Sweden and Norway is tough but weak and small or undersized, the best being converted into deals, etc.

[1] Curved cracks or openings formed by the separation of the annual rings.

[2] Cracks or splits right across the heart, dividing the log into segments; or a number of cracks radiating from the centre in the form of a star.

That from Sweden averages from 10 to 12 inches square, and from Norway about 8 or 9 inches. Being cheap and in small sizes, it is much used for staging and scaffolding.

The term Baltic *fir*, Memel *fir*, etc., always implies red pine in balk, though the term *pine* is confined in the trade to American shipments.

White Fir or Spruce.—Very little white pine (spruce, or *Abies excelsa*) comes into the market as square timber, when it does, it is distinguished as *white timber* or *spruce fir;* but spruce poles, or the young trees merely felled and stripped of their branches, are largely imported for scaffolding and as ladder poles. They run from 20 to 50 feet long (see pp. 125, 126).

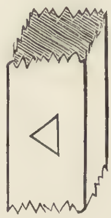
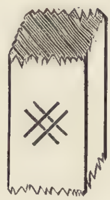
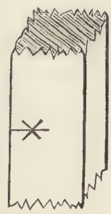
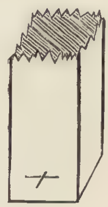
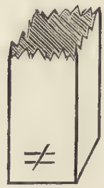
Shippers' and Quality Marks.—The different qualities of Memel and Dantzic timber are known as *crown, first* or *best middling, second* or *good middling, third* or *common middling;* whilst inferior balks are classed as "short and irregular."

Memel balks of first, second, and third qualities, are almost always scribe-marked, at one end of the balk; but these marks must not be mixed up with the number of float or raft, which is also scribed at one end of each balk, and the distinguishing number of balk in the float, which, with the cubic content, is scribed about the centre of every balk floated in the docks, where timber of the same shipment and quality is roped together in separate floats or rafts, and an accurate registry kept of the cubic content, and what becomes of each piece.

The scribe marks on Baltic timbers are often very numerous and perplexing, most of them being private marks put on by those through whose hands the timber has passed after being squared. On Dantzic they are much more numerous than on Memel or Riga timber; but with these marks of ownership we have nothing to do; all we care about are the brackers or sorters marks, distinguishing the different qualities from each other.

The following are the recognised marks for the middling qualities. Very little crown timber is imported, being rarely used by builders, except perhaps for special Government purposes. Memel crown timber is marked as below, but with only a single stroke:—

QUALITY MARKS ON BALTIC TIMBER.

Port of Shipment.	First or Best Middling.	Second or Good Middling.	Third or Common Middling.
Riga. (Scribed at centre.)			
Memel. (Scribed at end.)			
Dantzic. (Scribed at centre.)			
Stettin. (Scribed at end.)			

Stettin timber is seldom marked unless to distinguish different qualities in the same cargo.

Some Riga shippers always use the quality marks for best and good middling, and others only when different qualities are shipped in the same cargo. The common middling quality is rarely shipped from Riga.

There is no absolute uniformity about these quality marks, as all shippers from the same port are not bound to adopt them, some using private marks of their own, either alone or in addition to the ordinary marks; the latter being seldom omitted on Memel or Dantzic balks.

The safest plan, in the case of large and important works, is to order the timber direct from a broker, selecting it out of shipments from houses who have earned a reputation, from the care with which their timber is *bracked* or sorted; for there is a great difference in the same market quality of timber from different shippers; one shipper's *good middling* being often nearly equal to another's *best middling.*

If, amongst a lot of good middling logs, one or two marked as common middling or best middling, as the case may be, are found, it does not always follow that any deception has been practised; the timber may have changed hands, and a balk here and there may have been considered by the last owner as too good for *common* or too bad for *best* middling, and been shifted into a *good* middling float.

The following are the private marks of some of the leading shippers of Baltic, chiefly Dantzic, timber. They are scribed on the balks near the centres, often close to those given on page 120, and may be taken as a true indication of the quality of the timber. They will sometimes indicate a quality lower than that represented by the scribe marks given above, which cannot always be relied on, except in so far as the timber is sure not to be better than represented. As the letters are very roughly shaped with the scribe, it will require some practice to recognise the marks. Each of the columns below contains the different private marks employed by the same firm for *crown, best middling, good middling,* and *common middling* timber respectively. The addition of R to the SK marks in the second column indicates Russian timber shipped by the same firm (S. Kœhne). The marks in the last column are used by the "Handel's (trading) Company":—

Crown .	SKK	SKK R	MK K	OHP K	S M 22 × 26 K
Best middling .	SK	SK R	MK	OHP	S M 22 × 26 |
Good ,, .	SK |	SK | R	MK |	OHP |	S M 22 × 26 ||
Common ,, .	SK ||	SK || R	MK ||	OHP ||	S M 22 × 26 [1]

[1] The figures 22×26 vary.

American Pine.—American fir timber—called *pine* to distinguish it from Baltic *fir*—is known in the English market as American *yellow pine, red pine, white pine* or *spruce*, and *pitch pine*, according to the nature of the wood; and is classed as 1st, 2d, and 3d quality, without, however, any distinguishing marks.

The chief ports for American fir timber are Quebec and St. John,—the best yellow pine being shipped from the former, and the best spruce from the latter.

Yellow Pine.—American *yellow pine* (*Pinus strobus*, or Weymouth pine, called in America *white pine*) runs in balks up to 60 and 70 feet long and 24 inches square. It is not nearly so strong or durable as the red pine, but is much lighter, and is therefore readily distinguished in the floating docks by the height it stands out of the water. It is admirably adapted for running mouldings and internal joiner's work, being very free from knots and easy to work, but inferior to Baltic fir for external work.

Red Pine.—American *red pine* (*Pinus mitis*, called in America *yellow pine*) very closely resembles Baltic fir, but it is not so strong or durable, nor does it grow so large as Dantzic and Memel timber, though it is said to be stiffer. Being very straight-grained and free from knots, it is valuable for joiner's work, where a stronger wood than the yellow pine is required, but is not much used in England, except on the west coast, being more expensive, in proportion to its quality and size, than Baltic fir.

White Pine or Spruce.—American *white spruce* is very similar to Baltic white timber, but, not being considered equal to it in durability or strength, does not command much sale in our market, though largely used in the west of England and Ireland.

It is the produce of two different trees—the *Abies alba* and *Abies nigra,* so named from the colour of their bark, though the colour of the wood is in both instances white. The black spruce timber is much the best, is more plentiful and grows to a larger size.

Pitch Pine.—*Pitch Pine* (*Pinus resinosa*) comes from the United States, but chiefly from the ports of Georgia, Savannah, and Pensacola. It is, on account of its dark grain, much used for treads of stairs, framing of doors, and other purposes, when varnish instead of paint is to be used.

The wood is heavy, feels sticky, and is as hard to work as oak; the great quantity of resin it contains, though it clogs the plane, makes it very durable, especially when continuously exposed to damp and water. It is very free from knots, and can be obtained from 11 to 16 inches square, and from 20 to nearly 80 feet long. Being subject to heartshakes and cupshakes, it is, if required for conversion, more economical to purchase it already cut into planks, which can be obtained from 3 to 5 inches thick, from 10 to 14 inches broad, and from 20 to 40 feet long. Balks from 50 to 70 feet long can be got, sawn square, and are most valuable for engineering purposes, such as piles, etc.

Selecting Timber.—In selecting timber by its appearance much practice and judgment is required. Crown timber should be free from visible imperfections of any kind, clean and straight in the grain; though imperfections may possibly be found on cutting the timber up. Good timber should be straight; if curved more than 5 inches in a length of 12 feet, it is termed *Compass* timber. Cupshakes, starshakes, and heartshakes (footnotes, p. 118) should be looked for at the ends, where also indications of the soundness or otherwise of the heart may often be found. If a fir balk is not dead or faulty at the heart, the scratching of a pin's point, or the ticking of a watch placed against one end, will be distinctly heard at the opposite end.

A white, yellowish-red, or red tinge at the heart is a sign of decay; if decidedly red, the timber is said to be *foxy,* foxiness being a sure sign that decay pervades the whole log. *Doatiness* is a greenish tinge due to sap or bad seasoning, and if present will be seen on cutting off chips at the angles of the log. *Dry rot,* due to damp, warmth, and want of ventilation combined, is detected by a dull sound when tapped; the wood is powdery, and often looks as if it had been charred, or the surface may be covered with a white silky growth.

The lower the quality of the balks the more knots and other defects will be visible, the knots will be coarser, larger, and often dead—dead knots frequently denoting decay at the heart. Soft and shaky hearts and much sapwood also bespeak inferior timber, as well as *wandering hearts*, or where the heart, instead of running straight through the log, travels first to one side and then to the other, which can be told from the grain of the wood. Fig. 108 denotes a straight, and Fig 109 a wandering, heart.

Again, if in Fig. 109 the wood is sappy at B but hearty at A, it shows that the heart is travelling towards the side A. In good timber the spine or heartwood should be visible on all four sides.

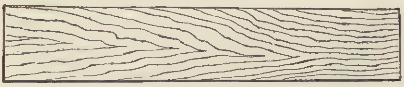


Fig. 108.

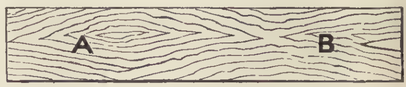


Fig. 109.

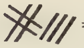
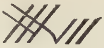
MEASURING AND VALUING TIMBER.—Much practice is required to value timber correctly by sight, therefore no opportunity should be missed of ascertaining the class to which timber belongs, and then noting the appearance of the grain, and the presence or absence of visible defects on the faces or ends of the balks, and of comparing balks of different classes when lying together.

In London the sectional area of square timber is measured by means of the Customs or Queen's *calipers;* but in Dublin, Glasgow, and other home and American ports, by string-measurement—by girthing the centre of the balk with string, and squaring one-fourth of the length of the string. This plan can only be applied with accuracy to square timber; but with round timber, the trade custom is the same as if it were square, the mean girth of the log being taken by string-measuring it at two or three points, three times the mean thickness of the bark being deducted, and one-fourth the remainder squared for the sectional area.

For the content of a round log stripped of bark, multiply the square of one-fifth of its mean circumference by twice its length.

In measuring with calipers nothing under $\frac{1}{4}$-inch is reckoned, and in the length nothing under 6 inches. Thus, a $12\frac{3}{4}$ by $13\frac{1}{4}$ inches by 30 feet 9 inches balk would be taken $12\frac{1}{2}$ by 13 inches by 30 feet 6 inches. In calipering square timber the London practice is to apply the calipers at the centre of the log and one-third down from two adjoining faces.

The cubic content as taken in the docks is scribed on one of the faces of each log, about its centre, on the following system :—

X = 10,  = 25,  = 43,  = 57,  = 74, etc.

Square timber is sold in London by the *load* of 50 cubic feet, and in some ports by the *ton* of 40 cubic feet; or by the 50 feet run, at a certain standard percentage over 12 inches square, according to its quality, as explained in the *Timber Importer's, Merchant's, and Builder's Standard Guide*, p. 51.

The relative value of different kinds of square timber, suitable for building purposes, may be seen from the following quotations from a list of current wholesale prices of timber:—

	per load of 50 cubic feet.			
Riga	63	shillings to	67	shillings.
Dantzic and Memel crown . . .	80	"	90	"
" " Best middling . .	70	"	80	"
" " Good " . . .	62	"	67	"
" " Common " . . .	52	"	57	"
" " Undersized . . .	52	"	60	"
" " Small, short, and irregular	45	"	55	"
Stettin	53	"	60	"
Swedish, 12 inches square and over .	53	"	55	"
" small, over 9 and under 12 .	47	"	50	"
Swedish and Norway, 9 inches and under	32	"	38	"
Quebec yellow pine	60	"	75	"
" Red pine	50	"	65	"
" Pitch pine	60	"	75	"

These prices, which of course vary with the state of the market, refer to ordinary building sizes, larger logs running much higher; thus, Dantzic logs 20 inches square would be as much as 120s. per load, and large-sized Quebec yellow pine logs about 90s. the load. Logs over 50 feet in length are valued at about $\frac{1}{10}$ more for every extra 10 feet in length.

Scaffold and Ladder Poles.—Young trees, both spruce and larch, of a suitable size, are felled, stripped of their branches, and exported, chiefly from Norway, for use as scaffold poles. They are classed according to the diameter of their butts, as over or under 4 inches, at an average length of 33 feet.

A "fair average" lot, in trade terms, would average 33 feet in length, 60 per cent being over 4-inch butts.

Those under $2\frac{1}{2}$ inches at the top ends are classed separately as *rickers*, running about 22 feet long, and are sold at from 1s. 7d. to 2s. each. The smallest sizes are called *spars*.

The London market price runs from about $1\frac{1}{2}$d. per foot run for from 4-inch to 6-inch butts, and 1d. per foot under 4 inches.

The following retail prices are quoted from the *Timber Importer's and Merchant's Guide for* 1871 :—

Scaffolding,	20 to 30 feet long	2½d. per foot run.	
,,	30 ,, 40 ,,	2½d. to 4d.	,,
Ladder Poles,	20 ,, 30 ,,	2½d. ,, 4d.	,,
,,	30 ,, 40 ,,	4d. ,, 5d.	,,
,,	40 ,, 45 ,,	5d. ,, 6d.	,,
Gross Poles,	30 ,, 40 ,,	6d. ,, 7½d.	,,
,,	40 ,, 45 ,,	7½d. ,, 11d.	,,

The gross poles are used for telegraph posts, and for cutting up for mine props. In the shipbuilding trade Norway spars are generally classed as—

Cants	average	36	feet long,	7	inch butts,	4	inch tips.
Barlings	,,	34	,,	6	,,	3½	,,
Booms	,,	32	,,	5	,,	2¾	,,
Middlings	,,	26	,,	3½	,,	1¾	,,
Smalls	,,	20	,,	2½	,,	1	,,

Trees not large enough for converting into deals, and too large for poles, are cut into lengths, and either squared or split in halves for sleepers.

Deal.

Fir timber, when sawn into convenient dimensions for purposes where large scantlings are not required, as in joiner's work, is termed *Deal.*

In this form it comes into the market, sawn into different widths known as *battens, deals,* and *planks,* varying from 1 to 4 inches thick, but principally 3 inches, and in length from 8 to 20 feet, but chiefly 12 feet; all under 8 feet in length being classed as *ends* and sold at a cheaper rate, the term "boards" being applied to battens, deals, and planks, under 3 inches thick.

They are termed *battens* when 7 inches wide and under, *deals* from 7 to 9, chiefly 9 inches, and *planks* over 9, but chiefly 11 inches.

Baltic Deal.—Baltic deal is either called *yellow deal,* in which case it is sawn from red pine timber (Scotch fir or *Pinus sylvestris*); or *white deal,* which is prepared from white fir (spruce or *Abies excelsa*).

Yellow Deal.—The best yellow deal for building purposes is shipped from the Russian ports of Petersburg, Onega, and Archangel, and the Swedish ports of Soderhamn, Gefle, Stockholm, and Holmsund.

Onega and Archangel, in the White Sea, furnish little but deals of the first quality. Petersburg deals are apt to be shaky, having a great many centres in the planks and deals, but the best qualities are very clean, free from knots, and rather more durable than those from the White Sea. Wyborg chiefly sends cheap and sappy battens.

Much of the Swedish timber is coarse and bad, but some of the very best Baltic deal, both yellow and white comes from Gefle

and Soderhamn. The best Swedish deals run more sound and even in quality than the Russian shipments, from the different way in which the timber is converted. A balk of Russian timber is all cut into deals of one quality, hence the numerous hearts or centres seen amongst them, which are so liable to shake and split; whereas in Swedish timber the inner and the outer wood are converted into different qualities of deal, hence first-class Swedish goods command a good price and, being more resinous and therefore harder, tougher, and more durable than Russian deals, are more suitable for carpenter's work; though for joinery first-class Russian deals both work up and stand better.

Four-inch deals should never be used for cutting into boards, as they are cut from the centres of the logs. Three-inch deals, the general thickness of Russian goods, are also open to the same objection. Swedish $2\frac{1}{2}$-inch and 2-inch deals of good quality are to be preferred to 3-inch, since they are all cut from the sound outer wood; although, being a novelty in the market and their value not understood, they are cheaper.

The only good Norwegian yellow deals come from Christiania, but they are very scarce now.

The export of deal from the Prussian ports of Dantzic, Memel, Stettin, etc., is almost entirely confined to yellow planks and deck deals, also called red deals, 2 to 4 inches thick, used for shipbuilding. The reason of this is that the timber from the southern ports, being coarse and wide in the grain, could not compete in the converted form, as deals, etc., with the closer-grained and cleaner exports from the more northern ports. Again, though hewn timber from the northern ports of the Baltic could be obtained of a cleaner and closer grain than that got from the south, the extra price charged would put it out of the market.

Yellow deals of good quality show the annular rings distinctly marked, of a reddish brown colour, whilst the wood gives off a strong odour of resin. The knots ought to be of a rich red-brown, and not brittle, thin shavings of them being semi-transparent. Amongst a lot of yellow deals many of them are sure to show sapwood at the edges more or less discoloured blue.

White Deal.—Some of the best white deal comes from Christiania, but that from the other Norwegian ports is not to be relied on, being apt to warp and split in drying. The best Russian white deal is shipped from Onega. Petersburg white deal, though finer and closer in the grain, shrinks and swells with the hygrometric state of the atmosphere.

Riga, about the most southern port from which deals are largely shipped, sends white deals only, which are inferior to those from Narva and Petersburg, being coarser and more open-grained.

In white deal the sapwood can hardly be distinguished from the heartwood, so that whenever sapwood is seen in deals it is a sure indication that the wood is not white deal. It does not give off the resinous odour of yellow deal, though resin is often found collected in hollows between the annular rings, which is not the case with yellow deal. The annular rings are not so marked or red coloured in white as in yellow deal, the knots are harder to cut, more brittle, and more liable to get loose, whilst thin shavings of them are of a dark brown colour and opaque.

White deal is not so durable as Baltic yellow deal, especially when exposed to the weather, but is much used for internal work, such as cheap doors and floors not subject to great wear and tear. It is also a nice wood for tops of dressers, shelves, and common tables, but, being liable to warp, it should not be cut too thin—not under an inch, if possible. For sticking mouldings and the finer kinds of joiner's work it is not fit, as the hard knots turn the plane-iron. Common Swedish white deals are used for making packing cases, etc.

Qualities and Brands.—Baltic planks, deals, and battens are as a rule, "bracked" or sorted as *Crown, Crown Brack, First Quality, Second Quality,* etc., down to even *Fifth* and *Sixth* (also called inferior fifth) in Swedish goods.

Very few crown, or crown brack, goods come into market, there being little or no demand for them for building purposes.

The different classes of deals, etc., will be found to vary very much in quality, one shipper's second quality being often equal to another's first quality. Hence some shippers have become well known for the greater care with which their goods are bracked or sorted, and their names or trademarks may be safely taken as a guarantee of a high standard in the different qualities.

Russian and Finnish goods are chiefly 1st and 2nd quality (the shipper's *prima* and *secunda*), and unbranded or only *dry stamped* —marked at their ends with a branding hammer, such marks being termed *hard brands.* It being quite the exception to brack Russian deals in more than two classes, the second class necessarily includes all the inferior stuff, consequently good brands of 1st and 2nd (classed together as *mixed*) and 3rd Swedish goods rank with 1st Russian or Finnish, 4th Swedish with 2nd Russian or Finnish, and 5th Swedish with 3rd Finnish.

Some good shipments from Uleaborg (Finland) are dry stamped U S for "mixed" (first and second quality unsorted), and U S in red paint for third quality goods.

Onega and Archangel deals are dry stamped with the shipper's initials, or private mark, and often with a number in addition, which, however, does not denote the quality, but merely the number of the yard in which they were stored before shipping.

In some cases, when the goods are not branded, the second quality have a red mark across the ends; third being easily distinguished from first quality goods.

The well-known Gromoff Petersburg deals are marked with C. and Co., the initials of the shippers, Clarke and Co. Another good Petersburg brand is P B (Peter Belaieff) for best or *prima*, and P B 2 for second quality or *secunda.*

Swedish goods are never hammer marked, but invariably branded with letters or devices in red paint, and in a few cases black, stencilled on the ends, which makes it difficult to judge of their quality by inspection, as they are stacked in the timber yards with their ends only showing. Some of the common fourth and fifth quality Swedish goods are left unmarked, but they may generally be distinguished from Russian shipments by the bluer colour of the sapwood.

In the English markets first and second Swedish deals are classed together as "mixed," being scarcely ever sorted separately; after which we get third, down to fifth and inferior fifth or sixth quality and unassorted goods. The French class the mixed as first, and our third as second quality, and so on, a more sensible classification.

Except for temporary purposes, or for rough work such as slate boarding, no deals of a lower quality than *mixed* Swedish, or, as the timber merchants and contractors would call them, *best* Swedish, should be used on Government works.

Amongst the Swedish brands which bear a high character (this refers to 1884; of course new brands are constantly coming into the market) are the following, taking each shipper's marks separately, under the heads of the chief districts only from which their shipments are made, and giving no quality marks below fourth:—

SODERHAMN.

Bergvik Steam Saw Mill Co.	B S S C	= mixed	J G G & Co.	= mixed
	B C	= 3d	G G G	= 3d
	B B B	= 4th	G G	= 4th

GEFLE.

	K A B = mixed	C ♕ B = mixed
	N A S = 3d	C ✠ B = 3d
	✶✶✶ = 4th	C ✠ ✠ B = 4th
Inferior Shipments have same marks in black.	A ♕ S = mixed	E K B = mixed
	A + S = 3d	E + B = 3d
	A ✶ S = 4th	E + + B = 4th
	K A B = mixed	S K B = mixed
	H A B = 3d	D O M = 3d
	H B L = 4th	D M = 4th

SODERHAMN, SUNDSWALL, AND UMEA.

Dickson, Bros. and Co. A well-known brand.	D B and Co. = mixed
	D D D = 3d
	D = 4th

GOTTENBURG.

J. W. Wilson	J W W = mixed
	J W = 3d
	W = 4th

STOCKHOLM.

J. E. Franke.	I ♕ F = mixed	S-holm at other end.
	I E F = 3d	
	I E F O = 4th	

UMEA.

♕ S Å S ♕ = mixed
S Å = 3d
S S = 4th

HERNOSAND.

Bergere = mixed
Berger = 3d
E L B = 4th

SUNDSWALL.

Burman and Co.	B ♕ C = mixed
	B ✶ C = 3d
	B + C = 4th

For the numerous other brands, whether on Baltic, American, or other timber, see Laxton's *Price Book;* and, for fuller information, the *Timber Trades Journal* List of Shipping Marks.

To give an idea of the value of the different qualities, the *mixed* are worth from 15 to 20 per cent more than third, and third from 12 to 15 per cent more than fourth quality.

It must be clearly understood that the term "mixed" is confined to the shippers and brokers. Timber merchants always call the mixed first quality or "best," and the third quality second quality, and so on, or one class higher than that at which they were shipped.

The Norwegian marks are very numerous, but, as the chief import is of cheap and very inferior battens (mostly 2½ by 6½), they are not worth enumerating here.

From Christiania, however, some of the very best white deals come, marked H M H for first quality, and H M M for second quality.

Norway also exports large quantities of cheap boards for flooring and other purposes, *match* or grooved and tongued boarding, mouldings, doors, window-sashes, etc., all ready for fixing, which may often be used with advantage for inferior or temporary purposes.

The following extract will show the value of obtaining correct information, year by year, relative to the best brand and quality marks, or of purchasing timber direct from the broker, when the contractor is not to be depended upon, instead of taking any stuff which he may consider good enough, with the attendant trouble of having continually to fight him on the subject.

"From these remarks it will be seen that brands upon timber is a great and important subject. It is one in the hands of a small community of our traders, and is, consequently, a class of knowledge over which they are strict conservators. It is a subject new to authors, and that portion of our tradesmen whose office it is to buy and consume timber. This is somewhat strange, as the meaning of brands are well known on other goods that people engaged in trade are called upon to purchase. With architects, clerks of works, and builders generally, brands upon timbers are looked upon with perfect indifference. The current remarks are 'I can tell a bit of good wood when I see it,' etc., and, as builders generally pursue the old-fashioned system of buying from inspection, the question carries but little importance. Why this state of things should exist is not easy to explain. Architects will specify a particular stone or brick, and even the name of the quarry owner or the maker. Such is the case in ironwork, slating, and every other department of the building trade; but with timber it is an open question, or if goods from a particular port are mentioned there is rarely any supervision exercised over the qualities. The modern system of competition tends to the use of common materials, and in no branch of the building trade is this so patent as in timber. Goods of the best brands were common a few years ago in almost every timber yard of the country, and in the principal ports they were important features of trade. Competition has brought on a craving for common or inferior goods, and nearly the whole of this trade is now carried on in this branch. First-brands are rarely found in timber yards, and even with the largest importers one or two cargoes will see them through a season. London alone has kept up its standard in this respect. Whether they are consumed in the building trade is

another matter; but one thing is certain, the great outcry of 'deterioration of timber' rests more with the architects and the builders than it does with nature or the foreign makers. Wood goods are to be bought as good in quality to-day as they were fifty years ago, as far as the best brands of Petersburg and Archangel deals are concerned. Coach-builders, pianoforte-makers, and numerous other trades, which are centred in London and Paris, consume the bulk of the best quality goods now manufactured. The explanation given by builders is, 'because they can afford to pay for them.'

"Were brands upon timber better known, architects would get better work, and builders would obtain greater credit. The cheap builder would find his place, and what are termed 'old-fashioned builders,' would again occupy the position they so richly merit. Fifty years ago, when competition was in its infancy, estimates were only solicited from builders who kept large stocks of good dry timber, but now everything is reversed. Tenders are advertised for in the public papers, and the lowest (be he whom he may) is nine times out of ten accepted as the contractor.

"So long as this system exists, so long will the demand for common goods increase to the exclusion of the better shipments. It is not saying too much to assert that builders have almost given up purchasing the old-fashioned best quality of timbers, and have allowed them to pass into other branches of trade where competition is not so fierce. As we have no published information upon the subject of marks on timber, it is not altogether a matter of regret.[1]

"A work of this kind would bear comparison with *Builder's Price Books*, a fresh edition being required every year. This would not be owing to fluctuations in the cost of labour, but to the fact that timber brands are constantly changing. New firms are shipping goods with strange brands, and old firms are changing their devices or retiring from the trade; added to this we have whole shipments of goods marked with the English merchant's or importer's names, this being done to order and forming part of the contracts. A well-known firm in this country are now importing Gottenburg goods with the thirds quality branded R W S. This 'branding to order' is becoming very common, and, as the ordinary business of importing timber requires a great deal of time, this may be readily done. Goods for the coming season

[1] Yearly lists of timber marks are now published, see page 130.

will be purchased in January or February, or as soon as the makers can inform their brokers what goods they can produce for the season. As they cannot be shipped until March, April, or May, when the ice is broken up in the northern seas and rivers, ample time is afforded for the importers to obtain their goods 'branded to order.'"

A series of valuable articles from which the above extract is taken, and which are well worth careful reading, are to be found in the following numbers of the *Building News*:—November 29th, December 27th, 1867; January 10th, 24th, February 28th, 1868.

AMERICAN DEAL—**White Spruce**.—American white deal (*Abies alba* and *Abies nigra*) is called *white spruce deal* (or American, Canadian, or New Brunswick *spruce*), to distinguish it from the *white deal* imported from the Baltic, to which it is considered inferior both in strength and durability; on which account there is not much sale for it in this country. White spruce deals, etc., are sorted into first, second, or third quality.

American Yellow Deal.—The yellow pine (*Pinus strobus* or Weymouth pine), when sawn into planks, deals, and battens, is termed *American yellow deal*, and is largely used for joiner's work, on account of its straight grain, freedom from knots, the ease with which it can be worked, and the large dimensions to which the planks run, as they can be got up to 30 inches wide. American yellow deals, when planed, are easily known, the surface being covered with short, fine, darkish marks, like scratches made with a pen in the direction of the grain; they are classed as follows:—

Brights . . .	1st, 2d, and 3d quality
Dry floated . .	,, ,,
Floated . . .	,, ,,

their order of merit being first quality brights, first quality dry floated, first quality floated, then second quality brights, and so on.

Brights are sawn from picked logs and have not been discoloured by being floated down the rivers, and are therefore of a much cleaner and brighter yellow.

Floated deals, etc., have been floated or rafted down the rivers from the felling grounds.

Dry floated implies that the deals, etc., have been stacked and dried before shipment.

First quality yellow deals of each kind should be clean, straight grained, and quite free from shakes and knots. Second quality are a little inferior in these respects, and third quality are inferior again.

The floating of the deals damages them considerably, besides discolouring them. The soft and absorbent nature of the wood causes them to warp and shake very much in drying, so that floated deals should never be used for fine work.

The best ports are Quebec for yellow deals, and St. John for spruce deals. Goods from the more southern ports, such as Richibucto, Miramichi, Shedac, etc., are of an inferior quality.

Rafted or floated deals are shipped from all the Canadian ports except St. John, hence the superiority of St. John deals, which are always bright or unwatered.

Brands.—American goods are not branded, as a rule, though some houses use brands, in imitation of the Baltic marks already described, but without following any definite rules. The qualities may, however, very often be known by red marks I, II, or III, upon the sides or ends; but the qualities of American yellow deals are easily told by inspection, the custom in the London Docks being to stack them on their sides, so as to expose their faces to view, and allow of freer ventilation.

How Sold.—Planks, deals, and battens, whether Baltic or American, are usually sold in London by the six score or long hundred (120 pieces) reduced to the Petersburg standard, which is a piece 12 feet $\times$ 11 $\times$ $1\frac{1}{2}$ inches, so that

Petersburg standard hundred $=$ 120 pieces 12 feet $\times 11 \times 1\frac{1}{2}$ inches $=$ 1980 feet super 1-inch thick $=$ 165 feet cube $=$ 1440 feet run of 11 by $1\frac{1}{2}$ inches $=$ 720 feet run of 11 by 3 inches.

The Petersburg standard of 165 feet cube is that chiefly employed, but the following standards are also sometimes used:—

				ft. cube.	ft. super.
London and Dublin	.	= 120	pieces $12' \times 9'' \times 3''$	= 270	= 1080
Christiania hundred	.	= 120	,, $11' \times 9'' \times 1\frac{1}{4}''$	= $103\frac{1}{8}$	= 990
,, ,,	.	= 60	,, $15' \times 11'' \times 1\frac{1}{2}''$	= $103\frac{1}{8}$	= 825
Quebec short hundred	.	= 100	,, $12' \times 11'' \times 2\frac{1}{2}''$	= $229\frac{1}{6}$	= 1100
,, long ,,	.	= 120	,, $10' \times 11'' \times 3''$	= 275	= 1100
Drammen ,,	.	= 120	,, $9' \times 6\frac{1}{2}'' \times 2\frac{1}{2}''$	= $121\frac{7}{8}$	= 585

Prepared flooring boards are sold by the *customary square*, which is a given number of feet run, as given below, varying with

the width of the board, but always so arranged as to approximate to the ordinary *square* of 100 feet super.

9 inch	8 inch	$7\frac{1}{2}$ inch	7 inch	$6\frac{3}{4}$ inch
140 feet	160 feet	170 feet	180 feet	185 feet
6 inch	$5\frac{3}{4}$ inch	$5\frac{1}{2}$ inch	$5\frac{1}{4}$ inch	5 inch
200 feet	210 feet	220 feet	230 feet	240 feet

The following extract from a price list will show the *relative* value of different descriptions of deals and battens, though the actual prices may be very different, according to the state of the market, whilst circumstances may even change their relative values :—

BALTIC DEALS AND BATTENS, PER PETERSBURG STANDARD HUNDRED.

	£	s.		£	s.
Archangel	11	10	to	12	10
,, seconds	9	0	,,	9	10
Petersburg	12	0	,,	13	0
Wyburg	9	15	,,	10	5
[1] Finland and hand-sawn Swedish	7	0	,,	8	0
Petersburg and Riga white deals	8	10	,,	9	5
Christiania deals, best sorts, yellow and white	10	0	,,	12	10
[1] Norway deals, other sorts	7	0	,,	8	0
[1] ,, Battens, all sorts	5	5	,,	7	0
Swedish and Gottenburg, good stocks	10	0	,,	10	10
,, Common and thirds	8	10	,,	9	10
Gefle and best Swedish deals	10	10	,,	12	10
Swedish battens	8	10	,,	10	10

AMERICAN DEALS, PER PETERSBURG STANDARD HUNDRED.

	£	s.		£	s.
Quebec pine, first quality, floated	16	0	to	17	0
,, second ,, ,,	12	0	,,	12	10
,, third ,, ,,	8	0	,,	9	0
Quebec pine, first quality, bright	18	0	,,	19	10
,, second ,, ,,	12	15	,,	13	10
,, third ,, ,,	8	0	,,	9	0
New Brunswick mixed pine	7	0	,,	8	0

[1] These goods might answer for some purposes, where it would be waste of money to use deals of a superior quality. The Finland and hand-sawn Swedish goods are frequently very fair in quality, but roughly converted, with hewn and *wany* edges (edges left rough, showing the outside of the tree, instead of being sawn square).

	£ s.		£ s.
Canadian spruce, first	8 15	to	11 0
,, second . . .	8 5	,,	8 15
,, third . . .	7 15	,,	8 0
New Brunswick, first	8 5	,,	8 15
,, second . . .	8 0	,,	8 5
,, third	7 5	,,	7 10
,, unsorted . . .	7 15	,,	8 10
Nova Scotia and Prince Edward's Isle .	7 0	,,	7 10
Battens, spruce	7 0	,,	7 10
United States pitch pine planks . .	12 0	,,	12 10

Sawyer's Work.

The form in which the sawyer has to deal with timber is either in round logs as it has come from the feller, or, in the case of timber imported into the market for building purposes, as square or whole timber, planks, deals, or battens, which, if not required in their full dimensions, must be reduced to given scantlings by sawing.

Square logs, as imported, are termed *whole timbers,* and when sawn down the centre they give two *half timbers.*

Timber is sawn to the required dimensions in a saw-pit, by two men working a large two-handle saw called a *pit-saw.* The line which has to be followed is chalked accurately on the upper surface of the wood which is placed over the pit, and two men, one in the pit called the pitman, and the other above called the topman, work the saw vertically up and down. The leading hand is the topman, whose duty it is to keep the saw to the line, hence the term *top sawyer* as applied to any one who excels in any particular work.

When much sawing has to be done a circular saw worked by machinery is used, the saw itself being stationary, and the stuff to be sawn fixed on a movable bench, which, being self-feeding, keeps the wood continually working up against the teeth of the saw.

Sawing by machinery can be done at about half the cost of hand-sawing. In the 6th vol. of the *Corps Papers* (Old Series), will be found a full account of sawing by machinery; whilst descriptions and prices of the requisite machinery can be obtained from such sources as Appleby's *Handbook of Machinery,* and Bolling and Lowe's *Price Books.*

A good book of reference with regard to sawing, as well as all other wood-working machines, is a *Treatise on the Construction and Operation of Wood-working Machines,* by J. Richards, Mechanical Engineer.

Sawing Round and Square Timber.—In converting timber merely for the market, or for general use, the object aimed at is to make the most of each log by cutting it up to the best advantage, or it may be that balks of given scantlings are required, in both of which cases the sawyer must exercise his judgment in dealing with each log; but should it be necessary to obtain the strongest section, or the stiffest section, he sets to work by the following rules:—

In order to obtain the strongest beam to resist transverse stress, divide the diameter of the log into three equal parts (when a first-class balk is required the heartwood only should be taken, but generally the diagonal is run a little into the sapwood, so as to make the most of the heartwood); from the points so found set up perpendiculars, and from the points at which the perpendiculars cut the circumference, draw lines to both ends of the diameter, so as to form a rectangle, as shown in Fig. 110.

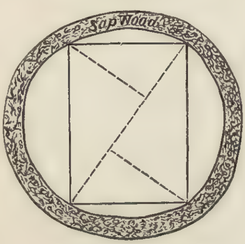


Fig. 110.


Fig. 111.

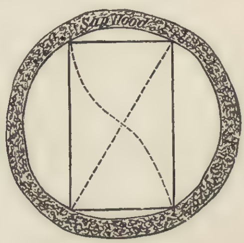


Fig. 112.

Should a beam be required to give a minimum deflection, divide the diameter into four instead of three equal parts, and proceed in the same way, Fig. 111; or lay off from each end of the diameter a line equal to one half the diameter, and complete the rectangle as in Fig. 112. By either of the last two methods deeper beams are obtained, though of a smaller sectional area than in Fig. 110; or, in other words, the maximum value of bd^3 is obtained.

In order to use the strength of timber to the greatest advantage, care should be taken in cutting up both round and square logs

into small scantlings, that the directions of the annual rings run as nearly as possible in the direction of the depth of the scantlings. Thus in Fig. 113, the batten *y* would be stronger than *x*, according to M. Buffon's experiments in oak, by about eight to seven.

The following extract is taken from a work on the *Strength of Materials*, by Mr. John Anderson, C.E., Superintendent of Machinery to the War Department:—

"If an oak or beech tree is cut into four quarters by passing the saw twice through the centre, at right angles, before the splitting and contracting has commenced, the lines *a c* and *b c* in Fig. 114 would be of the same length, and at right angles to each

Fig. 113.

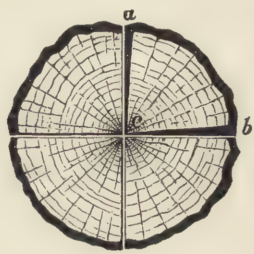


Fig. 114.

other, or, in the technical language of the workshop, they would be square; but after being stored in a dry place, say for a year, a great change will be found to have taken place, both in the form and in some of the dimensions. The line *a c* and *b c* will still be of the same length as before, but from *a* to *b* the wood will have contracted very considerably, and the two lines *a c* and *b c* will not be at right angles to each other, the angle being diminished by the portions shown in black in Fig. 114. The medullary rays are thus brought closer by the collapsing of the vertical fibres.

"But, supposing that six parallel saw cuts are passed through the tree, so as to form it into seven planks, what will be the behaviour of the several planks? Consider the centre plank first. After due seasoning and contracting it will be found that the middle of the board still retains the original thickness, from the resistance of the medullary rays, while the thickness will be gradually reduced towards the edges for want of support, and the entire breadth of the plank will be the same as it was at first, for

the foregoing reasons, and as shown in Fig. 115. Then, taking the planks at each edge of the centre, by the same law their change and behaviour will be quite different; they will still retain their original thickness at the centre, but will be a little reduced on each edge throughout, but the side next to the heart of the tree will be pulled round or bent convex, while the outside will be the reverse, or hollow, and the plank will be considerably narrower throughout its entire length, more especially on the surface of the hollow side. Selecting the next two planks, they will be found to have lost none of their thickness at the centre, and very little of their thickness at the edges, but very much of their breadth as planks, and will be curved round on the heart-side and made hollow on the outside. Supposing some of these planks to be cut up into square prisms when in the green state, the shape that these prisms will assume after a period of seasoning will entirely depend on the part of the tree to which they belonged, the greatest alteration would be perpendicular to the medullary rays. Thus, if the square was originally near the outside, as seen in Fig. 116, then the effect will be as shown in Fig. 117—namely, contraction in the direction from *a* to *b*. After

Fig. 115.

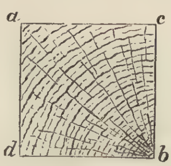


Fig. 116.

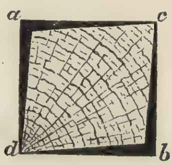


Fig. 117.

a year or two the square end of the prism will become rhomboidal, the distance between *c* and *d* being nearly the same as at first, but the other two edges brought closer together by the amount of their contraction. By understanding this natural law, it is comparatively easy to predict the future behaviour of a board or plank by carefully examining the end wood, in order to ascertain the part of the log from which it has been cut, as the angle of the ring growths and the medullary rays will show this, as in Figs. 118 and 119. If a plank has the appearance of the former, it must have been cut from the outside, and for many years it

will gradually shrink in the breadth; while the next plank, shown in Fig. 118, must have been derived from near the centre or heart of the tree, and it will not shrink in the breadth but in thickness, with the full dimension in the middle, but tapering to the edges.

"The foregoing remarks apply more especially to the stronger exogenous woods, such as beech, oak, and the stronger home firs. The softer woods, such as yellow Canadian pine, are governed by the same law; but, in virtue of their softness, another law comes

Fig. 118.

Fig. 119.

into force, which to some degree affects their behaviour, as the contracting power of the tubular wood has sufficient strength to crush the softer medullary rays to some extent, and hence the primary law is so far modified. But even with the softer woods, such as are commonly used in the construction of houses, if the law is carefully observed, the greater part of the evils of shrinking would be obviated. Hence also it is that when a round block, as a mast, is formed out of a tree, it retains its roundness because it contracts uniformly or nearly so, whereas if a round spar is formed out of a quartering of the same tree it will become an oval, or otherwise contorted towards that shape."

When from the heart not running straight through a tree the annular rings at one end of a log run diagonally across the section, as in Fig. 116, and at the other end as at x or y, Fig. 113, the balk will be sure to twist or curl in drying.

Such questions as the above are, as a rule, quite ignored, the only thing aimed at being to cut up the timber to the best advantage.

Sawing Deals, etc.—The ordinary modes of converting timber into deals are as follows (see Gwilt's *Encyclopædia of Architecture*, edited by Wyatt Papworth, p. 634):—

Fig. 120 gives one 9 by 3 inch deal, and two battens 7 by $2\frac{1}{2}$ inches. This is not a good plan, as it leaves the whole of the centre in the deal; but it is a common way of cutting up Russian goods, to make the most of the small sized trees.

Fig. 121 gives two 9 by $2\frac{1}{2}$ inch deals, and two 7 by $2\frac{1}{2}$ inch

battens. Fig. 122 gives two 9 by 3 inch deals, and two 9 by $1\frac{1}{4}$ inch deals.

Fig. 120.

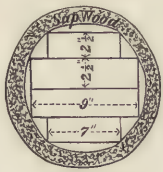


Fig. 121.

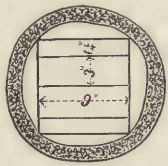


Fig. 122.

The outside pieces, curved on one face, are sold as slabs, and used for rough fencing, etc.

Oak, beech, and other timbers with medullary rays radiating from the centre, should, when cut into thin pieces, be converted in such a way that the rays may not run across the thickness of the stuff; otherwise it would split, twist, and warp, under the effects of changes in the weather.

A large log of oak to be converted into stuff for the joiner's use may be cut into four quarters and sawn up in different ways, according to the purposes for which it is required; the cuts following more or less the directions of the medullary rays.

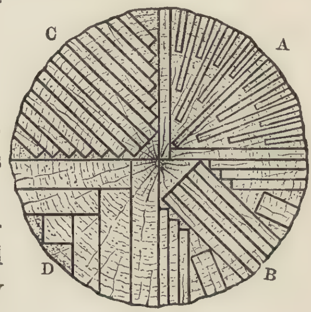


Fig. 123.

The best method is A, Fig. 123, there being no waste, as the feather-edged pieces can all be used up. B is the next best, then C; whilst D is the most economical for thick pieces.

The watered silk appearance, especially seen in Dutch wainscot, is obtained by cuts, as at A, crossing the medullary rays, or *felt* or *silver grain* as it is called, very obliquely.

Economy consists in using the ordinary market scantlings, or converting them to the best advantage, and not in wasting labour by adhering to theoretical dimensions, as extra material will often cost less than the labour of sawing.[1]

Planks, deals, and battens are largely used for cutting into small scantlings, such as 3 inches by 2, $2\frac{1}{2}$, $3\frac{1}{2}$, 4, $4\frac{1}{2}$ inches, etc., which are, if cut from good deals, better than those cut from whole timbers, though the contrary is the most generally received opinion. In proof of this, as has been already

[1] For the ordinary market scantlings, see Appendix VII.

pointed out, the export of planks, deals, and battens is almost entirely confined to the more northern districts, which produce the closest grained timber, whilst the coarser and more open grained timber, grown in the southern districts of Livonia and Prussia, is exported in balk, and, though superior in strength, when used in large beams, is unsuitable for cutting up into small scantlings, since the large scale of the knots and other defects would tell too much in small sections, where they would bear an undue proportion to the sound part of the wood.

Deals cut into thicknesses under 3 inches are known, according to their widths, as plank, deal, or batten *boards.* Deal boards 2 inches thick are sometimes called *whole deals,* and when under 2 inches *cut deals.*

For the joiner's use the parallelism of the cuts—which is insured in the case of sawing by machinery—is most important, since the operation of taking out of winding, or bringing to a level surface, an uneven piece of stuff is very troublesome.

Valuing Sawyer's Work.—Sawyer's work, in the case of flat and deep cuts with the grain of the wood, should either be paid for by the square of 100 feet super, or by the 10 or 100 feet run; in the latter case the price varying with the depth of the cut—a *cut* always implying the two faces which joined each other, each face separately being called *half a cut,* so that every board with two sawn faces represents one cut. A 3-inch deal cut in three gives what are termed 3-inch deals or two cut stuff.

The deep cuts in planks, deals, and battens are measured net by the foot super; flat cuts or ripping, at not less than 3 inches deep; and cross cuts, or against the grain of the wood, per inch run, or at six times the amount of flat cuts; or, in the case of deals they may be numbered and paid for at the rate of 5 feet of flat cutting each.

Sometimes sawing is valued by the dozen cuts, when, as in deals of a fixed length and breadth, all the cuts are alike, but in the War Department Schedules all sawing is valued at per 100 feet super, except in the case of deals, which are valued at per 10 feet run, either as 3, 7, or 9 inch cuts.

The price varies with the nature of the timber and its condition, the cost of sawing dry seasoned timber being about one-fourth more than when new. The value of sawing on African oak, teak, and mahogany, is about two and a half times that on fir; and on oak, elm, ash, and beach, about two-thirds as much

again as on fir. Very thin cuts on hardwood are also paid for at a higher rate.

In sawing round and hewn logs and balks, half a cut should be added to the actual number of saw cuts for trouble and time expended in moving the timber and setting out the work; and the depth of the cuts on round logs should be taken at a mean between the greatest and the least depth of cut, no cut being rated at less than 4 inches in depth.

By using constants of labour for sawyer's work, as given in Hurst's *Handbook* and elsewhere, the time, and thence the net cost of sawing wood, can be readily ascertained. For instance, taking the time occupied by a pair of sawyers in sawing 1 foot super of deal at ·0025 of a day of ten hours, then multiplying the decimal by the number of feet super in the cuts, and that product by the wages paid, the net cost per foot super of sawing will be ascertained.

To the cost thus found must be added 10 or 12 per cent for superintendence and wear and tear of tools, plant, and premises.

Stacking Deals, etc.—The proper stacking of timber after it is cut up, so as to give free ventilation and prevent sweating, to protect it from rain and allow of its drying gradually, is a matter of importance.

The best methods of stacking converted timber are fully described in Newland's *Carpenter's and Joiner's Assistant*, where much valuable information may also be obtained on the best methods of bending, seasoning, etc.

CARPENTER.

Description of Work.—The larger scantlings with which the carpenter has to deal, and the comparative absence of that high finish which is essential to joiner's work, renders it almost impossible for the same man to be a first-class hand at both branches of the trade. A first-class joiner is always too slow and cramped at carpenter's work, and a first-class carpenter is not sufficiently attentive to those details which constitute highly-finished joiner's work.

Carpenter's work, as distinct from that of the joiner, consists of framing and fitting together all the woodwork connected with the proper construction and stability of a building or other kind

of structure. He supplies all the woodwork required to be built in or bedded on walls, such as *wall-plates, templates*, etc., for joints or girders to rest on; and *wood bricks* or *nogs, wood slips*, and *lintels*, for attaching the joiner's work to; besides which he should see to their being fixed in the right places if there is no one else to look after it. He provides, and fixes when required, all *centres* and *turning pieces* for arches, and *moulds* for inverts and drains. He constructs *roofs, floors, partitions*, and all other parts in which timbers are framed together, and fixes roof, weather, and other rough boarding.

Wood used.—The principal wood used by the carpenter is Baltic fir, either in balk or converted into deals planks, or battens, from which he can cut to advantage most of the scantlings in ordinary use. Oak he but seldom uses, and only when great strength is required.

Tools.—The carpenter's tools are chiefly confined to the axe, adze, saw, chisel, hammer, auger, and mallet, with his pencil, chalk-line, plumb-rule, level, and square. The plane he seldom uses, his timbers being generally left rough: in fact the plane may be regarded as the great point of separation between the carpenter and joiner.

Joints in Wooden Framing.

Framing, in carpentry, is the art of combining pieces of timber together, so as to make them mutually strengthen and support each other. However scientifically the different members of any framework may be arranged, its rigidity, strength, and durability, entirely depend upon the proper formation of the joints connecting its various parts together, and it is in these details that the skill of the carpenter is mainly tested.

The following remarks have been partly taken from the Article on "Joints and Fastenings in Carpentry," chap. iv. sec. 2, of Rankine's *Civil Engineering*, which is itself largely drawn from the works of Robinson and Tredgold on *Carpentry*.

Classification of Joints.—All joints, or surfaces brought in contact with each other, for connecting the different parts of any wooden framing—considered apart from the *fastenings*, or means employed for strengthening joints, and keeping their surfaces close together—may be classed under one of the following heads:—

I. Joints for lengthening ties.
II. Joints for lengthening struts.
III. Joints for lengthening beams.
IV. Joints for supporting beams on beams, plates, and posts.
V. Joints for connecting struts with ties.
VI. Joints for ties and braces.

Guiding Principles in making Joints.—In designing and executing all kinds of joints and fastenings, the following guiding principles must be observed :—

I. To cut the joints and arrange the fastenings, so as to weaken the pieces of timber as little as possible.

II. To place each abutting surface in a joint as nearly as possible perpendicular to the pressure it has to transmit.

III. To proportion the area of each part of the joint and fastenings to the maximum stress it has to resist.

IV. To form the joints, so that they may be affected as little as possible by the shrinking and expanding of the wood.

V. To form and fit the different parts of each joint, so that the stresses may be spread as uniformly as possible over the sections of the timbers and fastenings composing it.

In forming joints the carpenter should distinguish between the bearing surfaces and those parts merely intended to keep the timbers in their proper positions. The bearing surfaces require the most accurate fitting in order to distribute the stresses uniformly, but any unnecessary finish, where not required, is only labour expended in vain.

In order to guard as much as possible against careless workmanship on the working parts of joints, as well as against failures from their giving under the effects of decay or crippling of the fibres, those joints are preferable in which the bearing surfaces, or working parts, are thrown to the outside, and so exposed to view as much as possible.

It should be borne in mind that simple joints are much more likely to be truly and securely made than more elaborate ones, hence but few of those given in books are of much practical value, though many display an amount of ingenuity worthy of a better cause.

In the following description of the principal joints used in carpentry, none but those in common use, or worthy of being more generally employed, will be noticed.

Joints for lengthening Ties.

Timber ties may be lengthened either by *fishing*, which is the simplest and best method; or by *scarfing*, which is the most usual method.

Fished Joints.—In a *fished* joint the ends of the timbers abut square against each other, and are connected by means of *fish-plates*, either of wood or iron, which are bolted to them on two opposite sides of the timbers, and sometimes, though rarely, on all four sides.

In the plain fished joint, Fig. 124, the fish-plates, one of

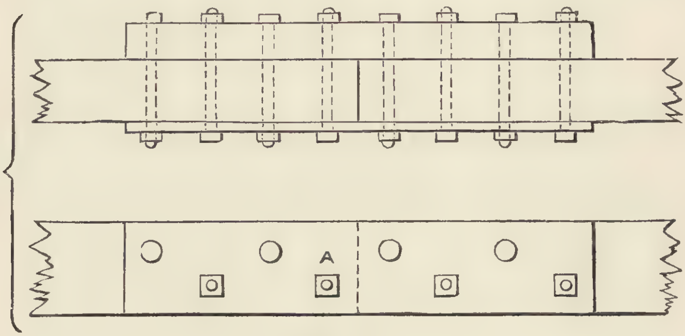


Fig. 124.

which is shown of iron and the other of wood, have plain surfaces, and the effective sectional area of the tie is only diminished to the extent of one bolt hole, as may be seen by the distribution of the bolts on the plan A; whilst the strength of these joints depends:—

1*st*. On the effective sectional area of the fish-plates being together equal in tensile strength to the effective sectional area of the tie.

2*d*. On the sectional area of the bolts being sufficient on either side of the joint to resist shearing, without placing any reliance on the frictional resistance to sliding between the surfaces of the fish-plates and the timbers; which, depending as it does on the tightness of the bolting, is constantly varying with the expansion and contraction of the materials.

In practice it is usual to take the sectional area of the bolts as equal, on either side of the joint, to at least one-fifth the effective sectional area of the tie; or, in other words, the safe resistance

of wrought-iron to shearing is taken at two and a half times the safe tensile resistance of the timber.[1]

3*d.* On the placing of the bolts in such a way, and at such distances from the ends of the fish-plates and butting ends of the timbers, as to prevent their drawing through them. With this view the sum of the joint areas on both sides of the pieces liable to be sheared out, whether in the tie or in wooden fish-plates, should, on either side of the joint, exceed the effective area of the tie in the same proportion as the tenacity of the wood exceeds its resistance to shearing in the direction of its fibres—viz. in fir timber, from sixteen to twenty times.

4*th.* The bearing area of the bolts must be sufficient to prevent their cutting their way through either the timbers or the fish-plates. It is in this way that fished ties are most liable to yield.

Fish-plates, instead of being plain, may be made to relieve the bolts of some of the shearing stress thrown upon them, by being *tabled*, *joggled*, or indented into the tie, as shown, in both iron and wood, in Fig. 125; or by hardwood joggles or keys, as in Fig. 126.

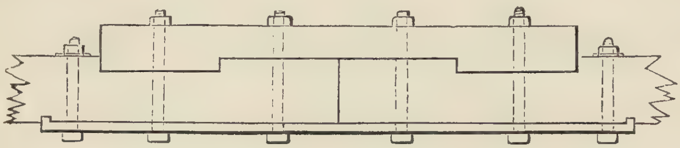


Fig. 125.

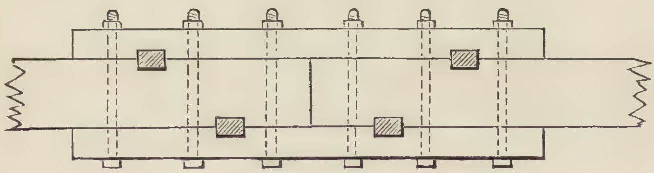


Fig. 126.

The use of indented wooden fish-plates diminishes considerably the effective area of the tie; but in the case of iron fish-plates, as shown in Figs. 125, 130, and 131, the depth and position of the indents may be arranged so as not to cut away more of the

[1] This takes the safe tensile resistance of fir per square inch at the high value of $\frac{12000}{4}$ = 3000 lbs., see Appendix VI., p. 329, which multiplied by $2\frac{1}{2}$ = 7500 lbs., giving the low value of about $3\frac{1}{3}$ tons per square inch as the working resistance of wrought-iron to shearing.

tie than is done by one of the bolts passing through it, and so not to diminish any further its effective area.

Iron fish-plates with indented ends may therefore be considered the best arrangement for a fished tie-joint, care being taken not to bring the indented ends of the plates opposite each other, which would unnecessarily diminish the effective area of the tie; and, for the same reason, the bolts should be arranged as shown in the plan A, Fig. 124, and not placed side by side; moreover, the bolts are better if made square, and passed through the timber, so as to present a square face at right angles to the direction of the stress, in which position they are found to cut into the wood less than round bolts.

Iron fish-plates have also the advantage over wooden ones of not shrinking and causing a loose joint.

Should the tie, when fixed, be out of the vertical, it should be placed so that the fish-plates may be on its upper and under surfaces, in order that they may most advantageously resist any bending stress, including that due to the weight of the tie itself.

Scarfing.—In *scarfed* joints the ends of the timbers to be connected overlap each other, as in Fig. 127, which represents a very common form of scarf, cut so that it will hold without the addition

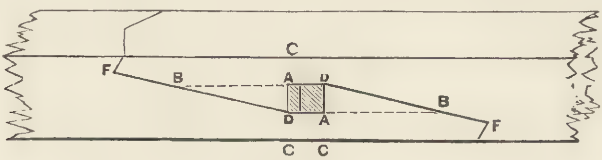


Fig. 127.

of any bolts or straps, two hardwood wedges being driven in at A, sufficiently to draw the joint up tight without overstraining it.

In tension joints the angle to which the surfaces F D are cut should, theoretically, allow of the resistance to shearing along A B being equal to the tensile strength of the section across A C; which should again be equal to the resistance to crushing of the bearing area presented by the vertical shoulders A D.

Now the shoulders A D—which are here cut at right angles to the direction of the stress, instead of to the surfaces F D, as is sometimes done—are usually made about one-third the depth of the beam. But if the crushing tensile and shearing strength of fir timber be taken—in the direction of its fibres—at 5000, 4000, and 600 lbs. per square inch respectively (see Table 1,

Appendix III.), in order to obtain a joint of uniform strength throughout, A B should equal nearly seven times A C, and A D should equal about two-fifths A C, since only about half the tensile strength of A C is utilised, owing to the stress not being transmitted through the mean fibre of the section.

It is therefore evident that this scarf is quite unfit to take up tensile stress, since, even if the shoulders A D = $\frac{2}{5}$A C, the effective tensile resistance of the tie is reduced to that due to about five-twelfths only of its sectional area, in addition to the loss of length caused by the overlap of the ends.

Fig. 128 is a similar form of joint, and to be preferred to Fig. 127 on account of its being easier to make.

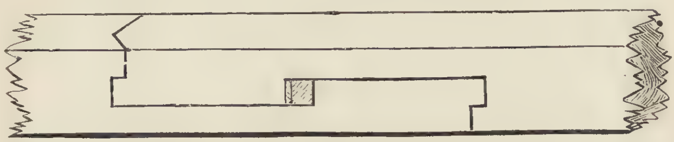


Fig. 128.

Fig. 129 is also a similar joint, though simpler and therefore better than either of the two last; A A are generally joggles of hardwood, and not wedged keys, but the latter are preferable, as they allow of tightening up. The shearing area along B F should, in fir, be not less than six and a half times B C; and B C should, in Fig. 129, be equal to at least twice the depth of the key.

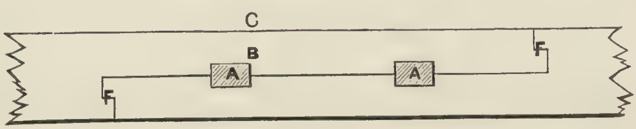


Fig. 129.

The shear in the keys being at right angles to the grain of the wood, a greater stress per square inch of shearing area can be put upon them than along B F, but their shearing area should be equal in strength to the other parts of the joint; oak is the best wood to use for them, as its shearing strength is from three to four times that of fir.

In all these cases the length of the scarf may be diminished, and its strength increased, by the use of iron bolts, either by themselves or in connection with fish-plates, in which latter case the joint may be, as in the case of one simply fished, made equal in

strength to the tie itself, less one bolt hole; though only by sacrificing the sole advantage which a scarfed has over a fished joint—namely, that it does not involve any increase in the sectional area of the tie at the joint, and may be concealed from view altogether, where appearance is an object.

If fish-plates are added to a scarf no advantage is gained by making the joint unnecessarily complicated. A plain fished scarf, similar to those given in Figs. 130 and 131, should in such

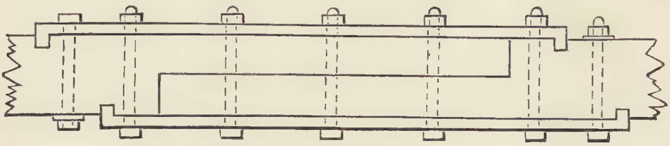


Fig. 130.

a case be used, Fig. 130 being preferable from the pressure of the bolts being applied at right angles, and so more effectually to the surfaces in contact.

There is no benefit gained, when fish-plates are used, by cutting the ends of the scarf as at F, F, Figs. 127 and 129; they are just as well left square as in Figs. 130 and 131.

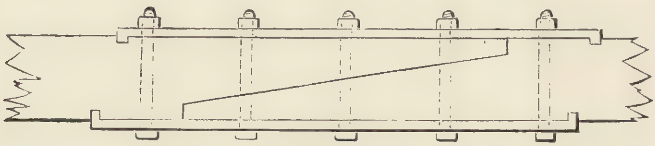


Fig. 131.

Tredgold gives the following rules—based upon the relative resistance to tension, crushing, and shearing of different woods—for the proportion which the length or overlap of a scarf should bear to the depth of the tie:—

	Without bolts.	With bolts.	With bolts and indents.
Leafwood (as oak, ash, elm) .	6	3	2
Pine wood	12	6	4

Scarfed joints with bolts and indents are joints such as Figs. 128, 129, and 130, only with the addition of bolts, the surfaces in contact being generally tabled or indented into each other; but such joints are not recommended; plain scarfs, strengthened by fish-plates, as Figs. 130 and 131, are much stronger.

From what has been said it will be evident that, for lengthen-

ing ties, a plain fished joint is the strongest and most economical, both in labour and material.

Joints for lengthening Wall-Plates, etc.—Timbers are often required to be connected together in the direction of their length, as in the case of wall-plates, etc., without being exposed to much tensile stress; in such cases they may be simply *halved* together,

Fig. 132.

and secured with nails, spikes, bolts, or screws, as in Fig. 130, supposing the fish-plates to be omitted; or they may be *halved* and *bevelled* as in Fig. 132, which, when loaded above, as is the

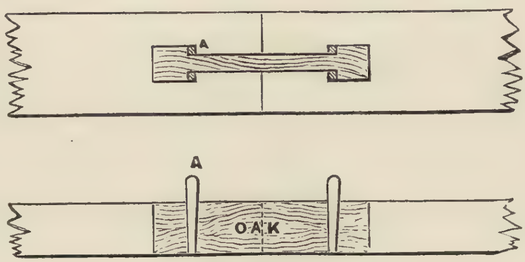


Fig. 133.

case with wall-plates built into a wall, gives them a good hold on each other. Figs. 133, 134, and 135, are other forms of joints used for similar purposes.

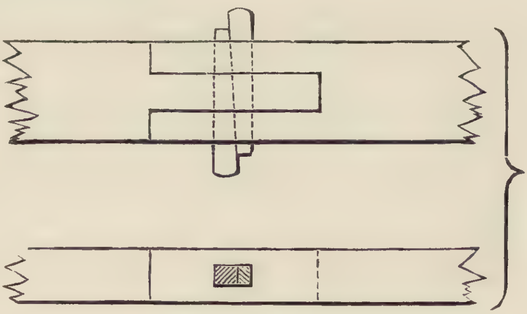


Fig. 134.

In Fig. 133 a double-headed key of hardwood is inserted into a cavity, cut to receive it in the ends of the timbers, and the

joint is drawn up tight by driving in wedges, A, between the ends of the timbers and the shoulders of the key.

Fig. 134 speaks for itself, whilst in Fig. 135 an iron bolt is screwed for half its length into the end of one timber, and passed through a hole bored to receive it in the end of the other, till it

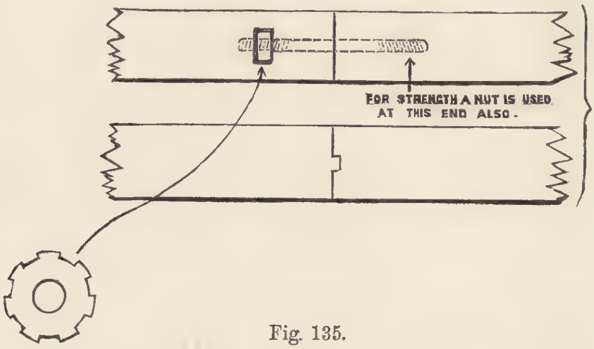


Fig. 135.

comes against a nut, dropped into a mortise hole cut for the purpose, which is screwed on, as the bolt is pressed home, by means of holes or notches cut round the edge of the nut. If a nut is used at both ends, one should be square, and fitted so as not to turn when screwing the other up.

Joints for lengthening Struts.

Fished Struts.—In lengthening struts, or timbers exposed to compression only, the two pieces should abut against each other, the surfaces in contact being cut at right angles to the direction of the thrust.

They should be fished, if possible, on all four sides, or have their abutting ends enclosed in an iron socket made to fit them.

Scarfed Struts.—If neither fish-plates nor iron sockets may be used, a plain scarf with square ends, secured by bolts similar to Fig. 130—only without the iron fish-plates—is the next best form to employ. Such a joint should be used for lengthening piles.

Joints for lengthening Beams.

Beams, or timbers exposed to bending stress, may be lengthened either by scarfing or fishing, and the joint should be placed where the bending moment is small, as at or near a point of support.

Scarfed Beam.—If a scarfed joint is used, the beam should

be fixed so that the surfaces of the scarf may be parallel to the direction of the bending stress, the joint being strongest when so placed (see Barlow *On the Strength of Timber*, art. lxxi.); but, whichever way it is placed, care must be taken that the abutting surfaces, on the compression side of the beam, are at right angles to the direction of the thrust.

Fished Beam.—When fish-plates are used the beam should be placed so that they may be on the compression and tension sides of the beam, in which positions they are working at the greatest distance from its neutral axis, and therefore to the greatest advantage.

Joints for supporting Beams on Beams, Plates, and Posts.

As mortising and tenoning is resorted to in many of the following joints, it will be well here to say a few words on the subject.

Mortise and Tenon Joints.—Fig. 136 shows a common

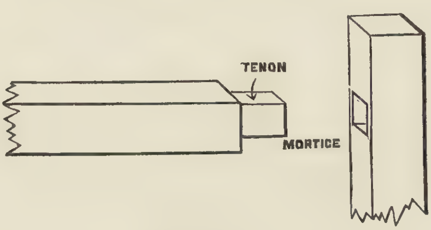


Fig. 136.

mortise and *tenon* or *joggled* joint, in which, if the tenon were fitted into the mortise, the strength of the joint, to resist every stress but direct tension or compression, would very much depend upon the strength of the tenon, which, in such a case, should be made as large as possible, consistent with not weakening the other timber too much by cutting too large a mortise hole. But when these two conditions cannot be fulfilled, other plans have to be adopted—such as the *shouldered tenon*, *housing*, etc., explained further on—in which the tenon proper merely performs the office of keeping the working parts of the joint in position. Whenever the mortise does not run right through the timber, the length of the tenon should be slightly less than the

depth of the mortise hole into which it fits, since the latter will diminish in depth as the beam shrinks in breadth, whilst no corresponding shortening of the tenon—in which the grain of the wood is in the direction of its length—will take place. If this is not attended to, the bearing parts of a mortise and tenon joint could not be made to fit correctly after shrinkage has taken place; whilst, in a compression joint, the stress would ultimately be thrown entirely on the end of the tenon, which must then be crippled before the bearing surfaces could again do their proper duty.

The long sides of a mortise hole are called the *cheeks* of the mortise; the plane from which the tenon springs is called the *shoulder* of the tenon; the part of the tenon adjoining the shoulder is called the *root* of the tenon; the parts round the mortise, against which the shoulders of the tenon butt, are called the *abutment cheeks.*

Fox-tail Wedging.—A tenon may be held tight in the mortise hole by cutting the latter to a dovetail and *fox-tail wedging* the tenon into it, which is done by sticking one or two thin wedges into, and projecting from, the end of the tenon, so that on coming in contact with the bottom of the mortise hole they may be

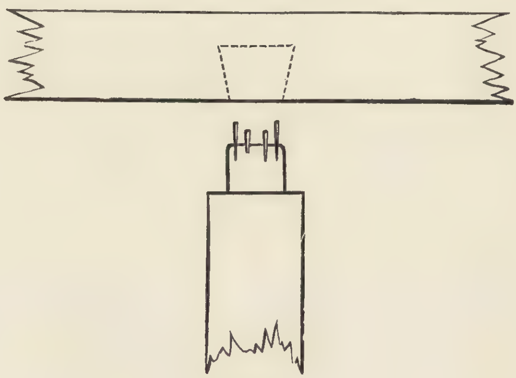


Fig. 137.

driven into the tenon, and enlarge it sufficiently to fill up the dovetailed mortise. In Fig. 137 four thin wedges are used, so arranged that the two outer ones may be driven first, and then the inner ones, by which means only thin pieces of the tenon are split and turned outwards at a time, in order to avoid the risk of splitting the tenon beyond the shoulder, which might possibly occur if fewer and thicker wedges were used.

Beams carried on the top of Beams, etc.—The simplest method of supporting one beam by another, whether the supporting beam is exposed to bending stress, as in a girder, or is merely a plate resting on a wall, is to allow the one to rest on the upper surface of the other.

Notched and Cogged Joints.—When it is desired to lower the upper beam, or to make it fit in between the timbers upon which it rests, it may be *notched* or cut away on the underside, as at *a*, Fig. 138, and it may be lowered still further by also notching

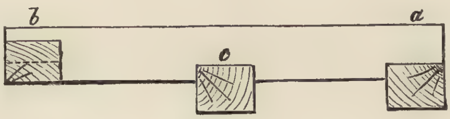


Fig. 138.

the upper side of the supporting beam as at *b*, which is called *double notching.*

When beams are required to hold each other in position, independent of any fastenings, the joint can be either *single* or *double notched,* as at *a* and *b*, Fig. 138, except that in addition to the underside of the top beam being cut away, its ends fit over and beyond the beam below as at *c*. If the top beam is notched to half its depth, and the beam below is notched to the same depth, so that the top surfaces of both are on the same level, the top beam is said to be *halved down* on that below. Another method is to use a *cogged* joint as in Fig. 139, where notches are cut on the top of the lower beam,

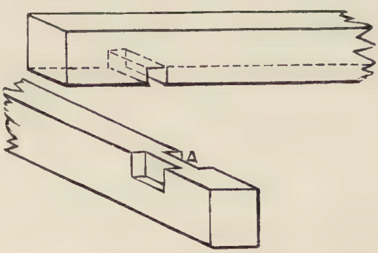


Fig. 139.

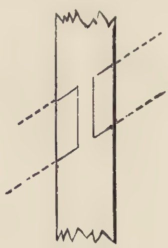


Fig. 139*a*.

leaving the cog A to fit over which a notch is cut on the underside of the top beam; by this means the whole depth of the top beam takes a bearing on that below, which, however, is more or less

weakened by the notches in its upper edge; for although they are afterwards filled in by the upper beam, still the shrinking of the wood in the direction of its breadth more than its length would prevent the filling in being sufficiently perfect to take the compression, until the lower beam has deflected sufficiently to allow of the surfaces coming into bearing.

Fig. 140 shows another form of a cogged joint, by using which the underside of the beam is not so much cut away.

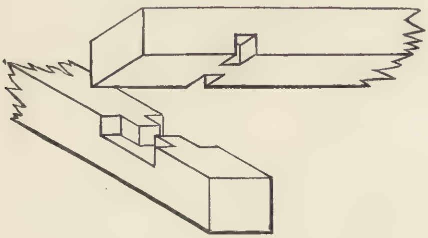


Fig. 140.

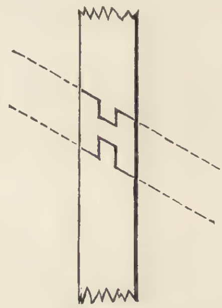


Fig. 140*a*.

Where the end of a beam is supported on another, as on a wall-plate, the advantage of a cogged joint can be obtained by cutting a single notch only in the lower beam, as shown in Fig. 141.

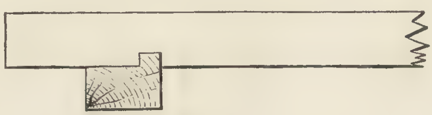


Fig. 141.

This joint, as well as that in Fig. 139, is useful when the end of the supported beam has to be cut off close to the point of support. In such cases, also, dovetailed joints, as Fig. 142, are often used, but in thick pieces of timber they are apt to draw, owing to the shrinkage of the dovetail in its width.

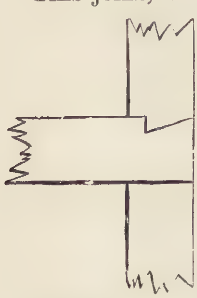


Fig. 142.

The cogged joint guards against both lateral and longitudinal movement, where it is advisable to do so, but the notched joint is simpler and, as far as the supporting beam is concerned, stronger.

Figs. 139*a* and 140*a* are plans of cogged joints where the timbers cross one another at other than a right angle.

Birdsmouth.—A simple notch is often cut on the underside of an inclined beam, as in the case of the feet of the common rafter, shown in Figs. 143 and 144, which fits over the edge of

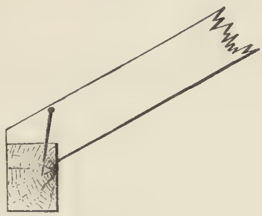


Fig. 143.

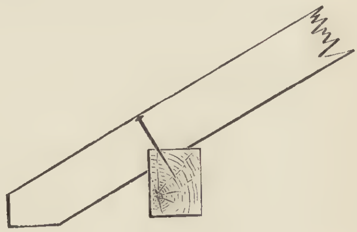


Fig. 144.

the plate on which it rests. This is called a *birdsmouth*, and sometimes a *sally*.

Beams supported on the Top of Posts.—When a beam rests on the top of a post, a shallow tenon, cut on the head of the latter, may be made to fit into a mortise hole cut in the underside of the beam, the mortise being, for the reasons already pointed out, a little deeper than the tenon. In order not to diminish the bearing area at the top of the post too much, the

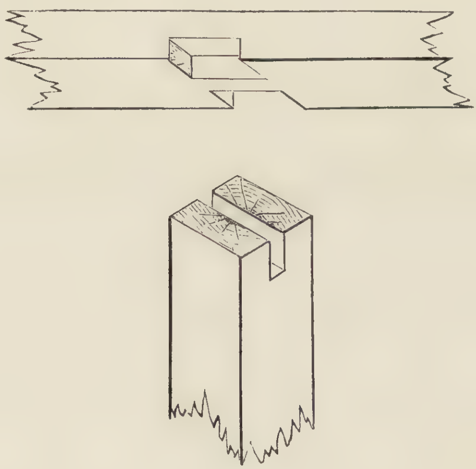


Fig. 145.

tenon should not be made larger than is absolutely necessary for security.

Instead of a tenon on the head of the post, the underside of the beam may be notched, leaving a bridle or cog to fit into a corresponding sinking in the head of the post, as shown in Fig. 145. The notches are sometimes made triangular or curved, as shown in Fig. 146, with the idea of insuring a more equal

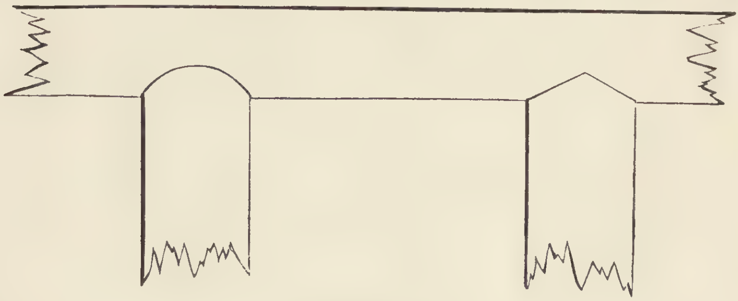


Fig. 146.

bearing in case of the timbers getting slightly inclined towards each other. However, a mortise and tenon is preferable to either of these joints.

Posts on Beams.—The same joints as are used for beams resting on posts are applicable to the feet of posts resting on beams or plates.

Beams carried on the Sides of Beams.—When it is desirable to economise vertical space, as in reducing the depth of framed floors, instead of a cross-beam resting on the top of a main beam, it may be carried, either by being framed into the side of the main beam, or—which are simpler plans, and avoid weakening the main beam by cutting into it—either by iron shoes secured to the sides of the main beams, or, by the cheaper method, of ribbands or fillets of wood (pieces 3 by 2 inches and under are called fillets) spiked or bolted on to their sides, on the top of

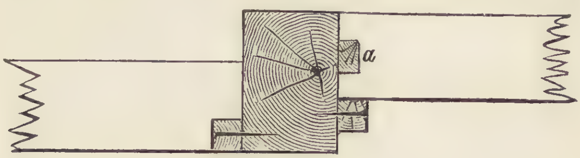


Fig. 147.

which the cross-beams may be made to rest, or may be notched, according to circumstances, as in Fig. 147. Sometimes the fillet

is placed, as shown at *a*, without the lower one; which, however, may be used in addition where any great weight has to be carried. When a single fillet is used, it is evidently the better construction to place it as low down as practicable. Care must be taken that the spikes or bolts attaching the ribbands to the main beam can resist safely the greatest stress which could be put upon them.

Shouldered or Tusk Tenons.—When the end of the cross-beam is framed into the side of the main beam, the joint is made by cutting what is termed a *shouldered* or *tusk tenon* on the end of the cross-beam, which fits into a corresponding mortise hole cut in the side of the supporting beam, as shown in Fig. 148.

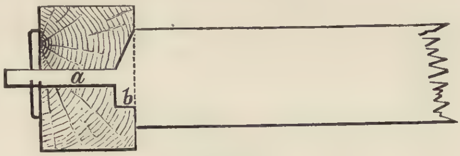


Fig. 148.

The long tenon *a* is made either long enough to pass right through the supporting beam, and admit of a tapered wooden pin being put through it to keep it in position and prevent the tusk *b* getting out of its bearing; or, when that cannot well be done, it is made about twice as long as it is deep, and a wooden pin or

Fig. 149.

iron bolt driven through it from the top of the main beam, as in Fig. 149; or, better, an iron screw bolt and nut may be used instead of the long tenon, as shown in Fig. 150.

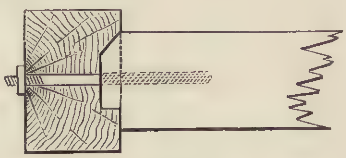


Fig. 150.

In each of these figures the tusk does the whole work of support, whilst the shoulder at the top of the beam is cut back, so as to avoid weakening the main beam more than is absolutely necessary, or the tusk tenon by cutting away too much of the wood above it.

The mortise hole for the long tenon should be placed as near as possible to the neutral axis of the main beam, with the view of weakening it as little as possible, and the tenon should not be thicker than required to allow of its being firmly secured in position, usually one-sixth the depth of the cross-beam itself.

The tusk—which should have a depth of bearing equal to about one-sixth the depth of the cross-beam, and should not be more than one-third the depth of the cross-beam from its under surface—must be kept at a safe distance above the bottom of the main beam, the exact position depending, within safe limits, upon the level at which it is desired to fix the cross-beams.

Fig. 151.

When the beams are deep, more than one tusk is sometimes used, as in Fig. 151; but this is not a good plan, as, however accurately fitted at first, the shrinking of the wood will soon make the upper and weaker one do an unfair share of the work.

Chase Mortise.—There are cases in which cross-beams are required to be fitted in between girders in position, as in renewing a defective one; when this has to be done, and a mortise and tenon joint is used, a chase, leading into the mortise hole, has to be cut, as shown in horizontal section in Fig. 152. By inserting the tenon at the other end of the beam into a mortise, cut so as to allow of getting it in at an angle, the tenon can be slid along the chase *b* into its proper position. It is better in this case to dispense with the long tenon, and, if necessary, to substitute a bolt as in figures 150, 152. A mortise of this kind is called a *chase mortise;* but an iron shoe secured to the girder forms a better means of carrying the end of a cross-beam, as it saves cutting into and weakening the girder.

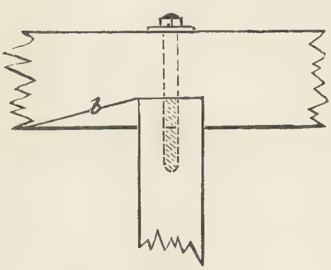


Fig. 152.

Beams carried on the Sides of Posts.—To support the end of a horizontal beam on the side of a post, the joint shown in Fig. 153 may be used, where the mortise for the long tenon is placed so as to weaken the post as little as possible, and the

tenon made about one-third the thickness of the beam on which it is cut. The amount of bearing the beam has on the post must greatly depend on the work it has to do. A hardwood pin can be passed through the cheeks of the mortise and the tenon to keep the latter in position, the holes being bored, so that they have to be brought concentric by driving in a tapered iron pin called a *draw-pin*, which draws the shoulder of the tenon tight home against the post, care being taken not, by too great violence, to shear out the wood between the pin and the end of the tenon.

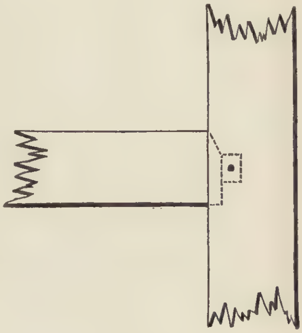


Fig. 153.

Instead of a mortise and tenon, an iron strap, or a screw bolt and nut, may be used, similar to that shown in Fig. 150.

The end of the beam may also be supported on a block which

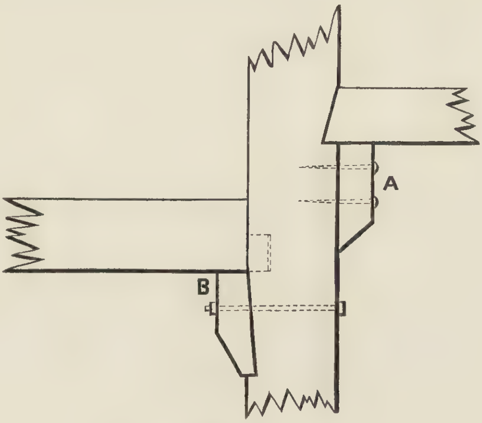


Fig. 154.

should be of hardwood, spiked or bolted on to the side of the post, as at A and B, Fig. 154.

In post and rail fences the rail either runs through mortise holes sunk right through the posts, the ends being cut so as to overlay each other, as shown by the dotted lines in Fig. 155, or they are *housed* and mortised into the side of the post, as shown in Fig. 156, the *housing* being the sinking in the post to receive

the full section of the rail, from the bottom of which the mortise is sunk further into the post.

Strut and Tie Joints.

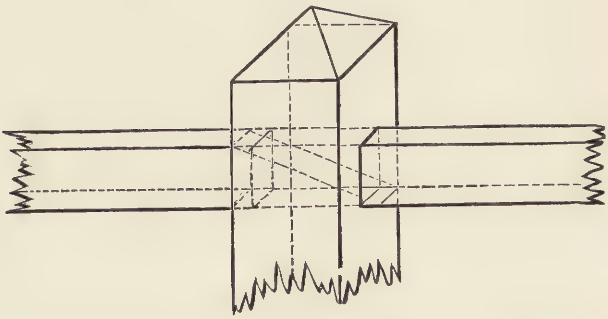


Fig. 155.

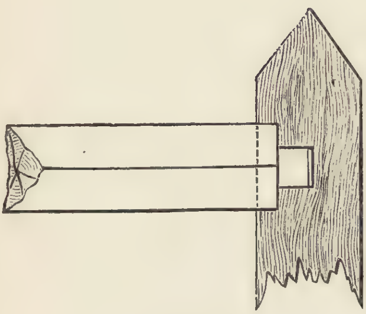


Fig. 156.

Straining Beams.—The joints shown in Figs. 147, 148, 149, 150, and 154, are equally applicable to horizontal struts or *straining beams*, fitted in between posts and ties, as in the ordinary queen-post roof-truss.

Framing of Struts into Ties.—When a strut thrusts obliquely against a tie, the joint must be formed so as to afford as good an abutment as possible to the ends of the strut, without weakening the tie too much. Fig. 157 is a good form for such a joint, and one that is largely used in roof-trusses for framing the foot of a principal rafter into a tie-beam. The considerations involved in proportioning the different parts of such a joint are fully entered into in the chapter on "Joints and Fastenings," in the volume of *Instruction in Construction*, by Major-General Wray, C.M.G., R.E., revised by Colonel Seddon, R.E.

The ordinary practice amongst good workmen, and the general rule laid down by writers on carpentry, is to make the shoulders *a b* equal to at least half the depth of the strut or rafter A; and to cut *a b* at right angles to the direction of the thrust, or else to

make *a b c* a right angle. The former is thought by some the better plan of the two, as it leaves the angle at *b* less acute, and therefore less liable to injury in case of an unfair proportion of the thrust coming upon it from the settling down of the timbers, due to the shrinking of the wood and its compression at the joints under the load of the finished roof. The depth of the abutting shoulder *a b* may of course be increased with advantage, so long as the tie-beam is not cut away too much. If it were not for this consideration the abutting end of the rafter would be better cut square, and a shoulder of equal depth cut in the tie-beam, to receive it.

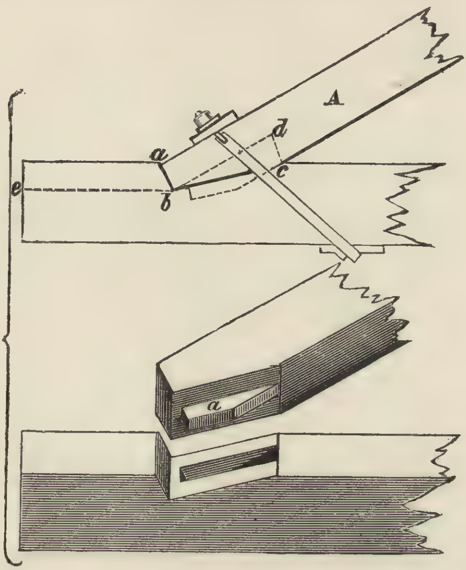


Fig. 157.

The tenon *a*, fitting into a mortise, prevents any lateral movement of the surfaces in contact, but should not be allowed to take any of the thrust. This tenon, which is made about one-fifth the width of the rafter, is not necessary when the joint is secured, as it always should be in a roof-truss, by iron fastenings; but the custom is to use it whether required or not.

Another similar form of joint often employed is that shown in Fig. 158; but the difficulty of getting the two parallel abutments to take their fair share of the work, both from want of accuracy in workmanship, as well as from the disturbing influences of shrinkage, is sufficient to condemn all such joints.

In making these joints, care must be taken that sufficient wood is left between the abutments and the end of the beam, to prevent its shearing off along *b e*, Fig. 157.

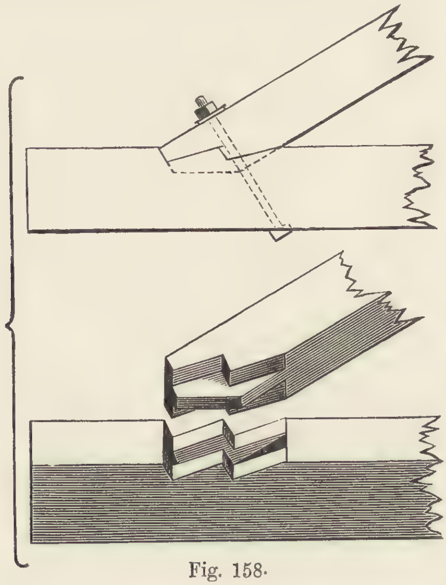


Fig. 158.

Fig. 159 shows a form of joint often used, in which a *bridle*, generally about one-fifth the breadth of the tie-beam, is left in the notch, which certainly has the effect of adding to the resistance to shearing along *e b*, and might therefore be used with advantage when the distance between the shoulder and the end of the tie-beam is unavoidably short; though the abutting end of the rafter is undoubtedly weakened by the cutting into it, to allow of its fitting down over the bridle. In the upper figure the heel of the rafter is cut so as to give a square bearing to the heel strap.

The foot of the principal may be kept in position by a bolt passing through the tie-beam, as shown in Fig. 158; but whenever there is any doubt about the shearing area being sufficient, the thrust should be partially, if not entirely, taken up by means of iron fastenings, such as stirrup irons, shoes, and bolts, rather than by having recourse to special forms of joints.

Heel straps, in order to meet the thrust down the rafter to the best advantage, should be inclined, as shown in Figs. 157 and 159, instead of being at right angles to the direction of the rafter,

as in Fig. 161. That shown in Fig. 157 is the best form; in which case bevelled washers or *check-plates*, as shown, should be used to present square bearings to the straps, instead of cutting

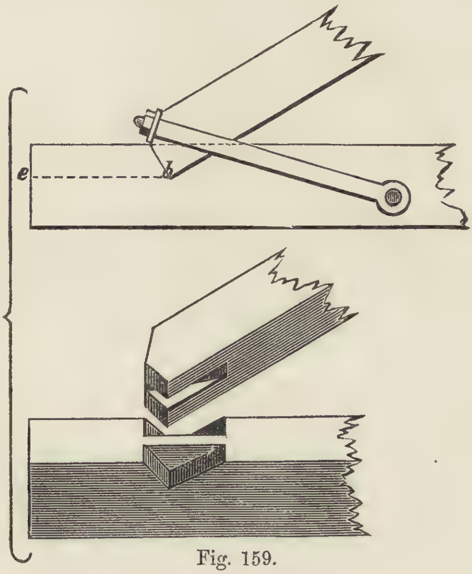


Fig. 159.

into the timber for that purpose; but, unless secured, the top is liable to work loose by sliding upwards. The check-plates, which may be of cast-iron, should be made of sufficient size to reduce the pressure against the fibres of the wood within safe limits.

Circular shoulders, or abutting surfaces, have been recommended, with the idea of their adjusting themselves to the settlement of the different parts, due to the shrinkage of the timbers and the forcing home of the joints after loading; but sufficient benefit is not got from their use to make up for the extra labour and trouble involved in forming them.

In good work those parts which, if cut to fit exactly in the first instance, might afterwards have an undue proportion of the stress thrown upon them, are cut a little slack at first, so as to allow of every part eventually doing its fair share of the work; at the same time the yielding nature of timber allows of the joints giving a little, and so accommodating themselves to any slight settlement of the different parts.

The above joints, since they greatly weaken the tie-beam by

cutting into it, should, if possible, be placed either directly over, or close to, a point of support.

Where it is not thought desirable to form an abutment for the feet of the struts, by cutting into the tie-beam, the thrust may be taken by an iron shoe, as in Fig. 160, or by spiking or bolting a piece of wood—hardwood is the best—on to the tie-beam, as

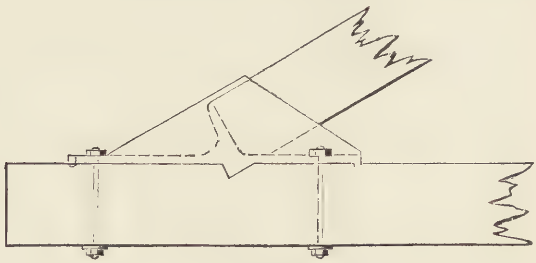


Fig. 160.

in Fig. 161, in which case a short tenon may be used to prevent lateral motion, or a strap, at right angles to the direction of the strut, to keep it down in its place; if a strap is used the tenon would not be necessary.

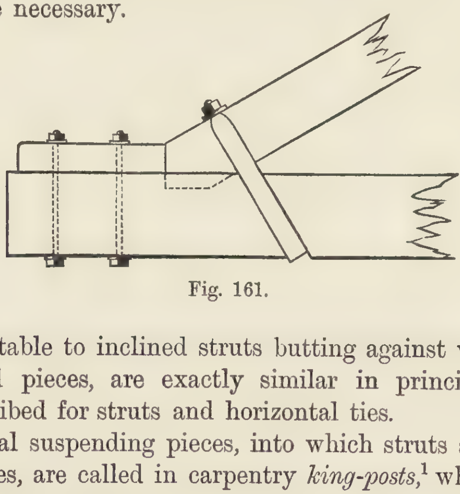


Fig. 161.

Joints, suitable to inclined struts butting against vertical posts or suspended pieces, are exactly similar in principle to those already described for struts and horizontal ties.

The vertical suspending pieces, into which struts are framed in wooden trusses, are called in carpentry *king-posts*,[1] when, as in the centre of a truss (Fig. 162), two struts butt up against it on opposite sides; and *queen-posts*, when, being out of the centre, as in Fig. 163, a strut butts against them on one side only. In such cases, especially in roof-trusses, the suspending pieces are generally left wider at their heads and feet, in order to form

[1] A more correct nomenclature would be *king-tie* and *queen-tie*.

abutting surfaces, which should, when practicable, be cut at right angles to the direction of the thrust, as in Fig. 162. When

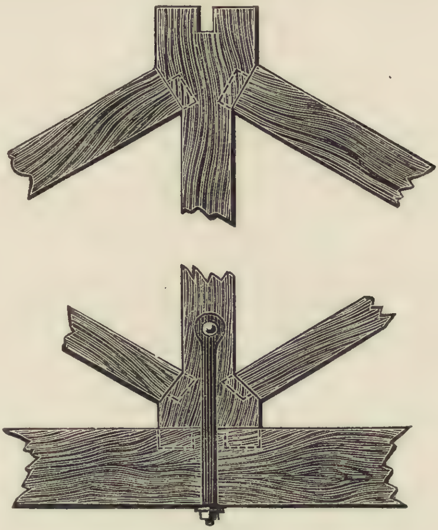
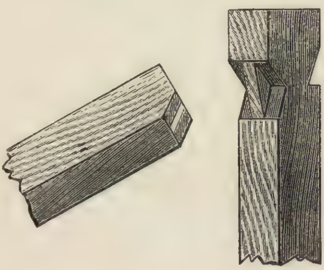
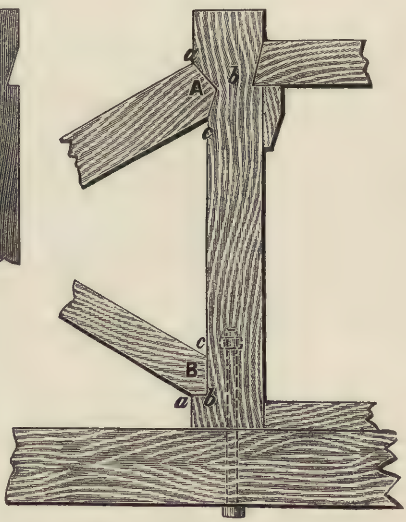


Fig. 162.

there is not sufficient width to do this, the joint should be cut as at A, Fig. 163, and not as at B.





When appearance has not to be considered, it is cheaper not to reduce the width of the king or queen post at all; in which case a joint such as A, Fig. 163, would be used.

Fig. 163.

Iron fastenings may be used to give additional security to these

joints; or joints similar to those given in Figs. 160 and 161 may be employed.

Instead of letting struts, such as in roof-trusses, butt against the sides of wooden king or queen-posts, which are liable to shrink considerably in breadth, and so to give rise to a general settlement, affecting more or less every joint in the truss, it is better to make the suspending pieces in pairs, as shown in Fig. 164, and let the ends of the struts pass between them and butt

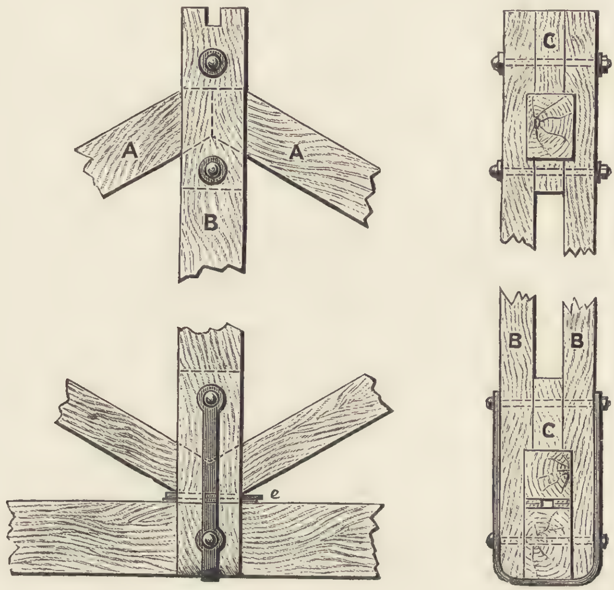


Fig. 164.

against each other. In the figure A A are struts or rafters butting against each other; B B the suspending pieces, notched in this case upon the rafters, though not necessarily in every case, and bolted together with filling in pieces, C C, and wedges at *e*, for tightening up as required. This arrangement is applicable chiefly to large roof-trusses; in narrow spans, where small kings or queens would suffice, it would weaken them too much to divide them.

When the suspending pieces are of iron, instead of wood, the ends of the struts are generally fitted into cast-iron sockets, as shown in Figs. 165, 166.

An iron shoe—one form of which, suitable for the foot of a

principal rafter, is given in Fig. 161—is the best abutment which can be given to the end of a strut, especially in the case

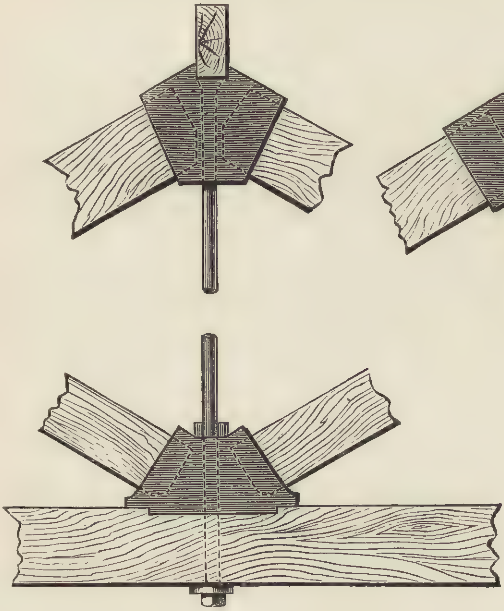


Fig. 165.

of the thrust having to be taken close to the end of a piece of timber.

Joints for Ties and Braces.

In most cases iron ties are to be preferred to wooden ones; but the latter have frequently to be used, both for the sake of stiffness, as well as from their having to take other stresses besides tension, as in the case of wall-plates, angle-ties, etc.

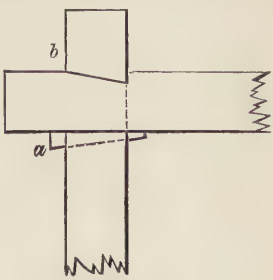


Fig. 166.

In carpentry, as already stated, dovetail joints, as in Fig. 142 and Fig. 166, should be carefully avoided, since the dovetail is sure to shrink across its breadth, *a b*, and allow the joint to draw. They are, however, sometimes employed for joints which have to be rapidly disconnected and put together; in which case, by using a wedge, as in Fig. 166, they

can be readily tightened up or loosened. In joinery, the wood used being in much smaller pieces, drier, and better seasoned, this objection to dovetailing does not hold good.

In some cases a simple notched or cogged joint, as already shown in Figs. 138, 139, 140, and 141, would answer the purpose; whilst, if it is necessary that the surfaces of the timber should be flush, the pieces must be *halved* into each other as in Fig. 167, or to half the depth of the shallower of the two, when they are not of equal depth. When the timbers do not cross each other sufficiently to allow of a simple halved joint,

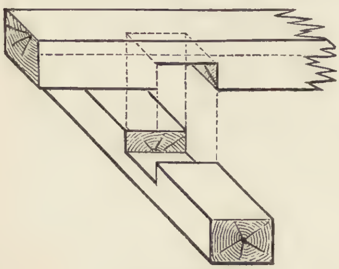


Fig. 167.

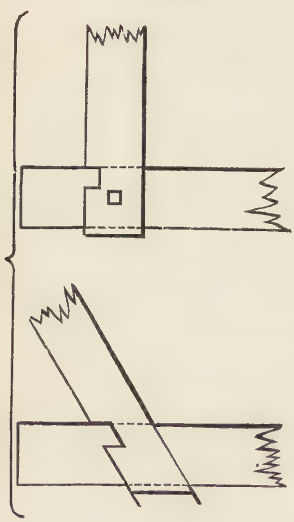


Fig. 168.

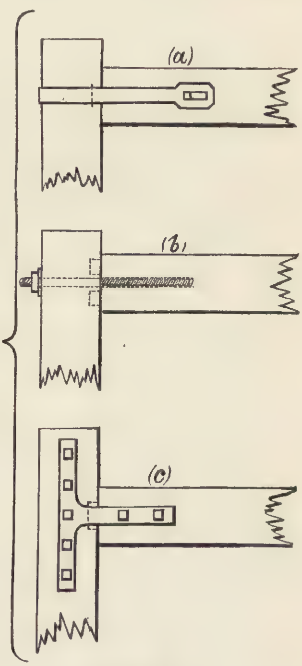


Fig. 169.

security may be obtained by using a joint as shown in Fig. 168; a wooden pin or iron bolt being added for further security if thought advisable. Of course, if the surfaces of the two scantlings are not required to be quite flush, the depth of the notch or halving can be regulated accordingly.

The difficulties attending the proper formation of these joints are readily got over by using iron fastenings, as shown at *a, b,*

and *c*, Fig. 169, in which *a* and *b* admit of being tightened up after the wood has shrunk, and are therefore to be preferred.

Fastenings.

Fastenings in carpentry may be classed as follows:—

I. Those exposed chiefly to shearing and bending stress—such as pins and treenails, spikes, nails, screws and bolts.

II. Those exposed chiefly to tension—such as straps and tie-bars, including stirrup irons and suspending rods.

III. Those exposed chiefly to thrust—such as iron shoes and sockets.

Fastenings exposed chiefly to Shearing and Bending Stress.

Wooden pins, Treenails, and Wedges.—Pins of hardwood are used by carpenters to add to the security of joints; when of large diameter they are called *treenails.* They should be made of well-seasoned wood, otherwise they will shrink and get loose.

From experiments on the cross breaking of treenails, recorded in Murray on *Shipbuilding*, the ultimate resistance to shearing of English oak treenails may be taken at about 4000 lbs. per square inch of section, provided the thickness of the planks connected by them, or the depth of the treenail hole, is at least three times the diameter of the treenail.

Nails, Spikes, Screws, and their holding power.—Hardwood wedges and keys are often used to tighten up joints, as shown already in Figs. 126, 127, 128, 129, 133, and 134.

For the results of experiments made on the force required to draw nails and spikes of different kinds, driven into various descriptions of wood, see Rankine's *Civil Engineering*, ninth edition, p. 460; also *R. E. Professional Papers*, vol. xxi., paper 15, by Captain Fraser, R.E.; who sums up as follows:—"In fir timber the holding power in lbs. is—For iron dogs, from 600 to 900 lbs. for each inch in length of spike; for spike nails, from 460 to 730 lbs. per inch in length, exclusive of thickness of cover-plate; for oak, ash, or beech treenails, 2000 lbs. per square inch of section; for fir (Scotch), spruce, or elm treenails, from 1000 to 1200 lbs. per square inch. The holding power of spikes in hardwood is increased approximately one-third. All the treenails were of

seasoned wood. Further experiments with green oak and unseasoned Scotch fir gave a mean holding power per square inch of 2190 lbs. for the oak, and 1500 lbs. for the fir."

When strength is required, *wrought* or hand-made nails should be used; for common work, and where, as in flooring boards, they are not exposed to cross stress, machine-made or *cut* nails, as they are called, which are cheaper, may be used. Cut steel nails are now manufactured.

Nails or spikes, for fastening boards and planks to beams, should be at least twice the thickness of the boards; two and a half times is a good secure length.

The different kinds of nails and screws used, and how they are sold, will be given under the head of "Ironmongery."

Hurst's *Edition of Tredgold*, p. 324, gives the results of some experiments made on the force required to draw screws out of wood; from which it is deduced that, as a rule, the force in lbs. required to draw screws out of hardwood is 200,000 $d\ b\ t$, and half as much out of soft wood—where $d =$ diameter of screw, $b =$ depth of thread, and $t =$ depth driven into the wood, all in inches.

Bolts, Nuts, and Washers.—Care must be taken that all iron bolts, straps, and tie-rods, used in carpentry, are made of ductile iron, capable of bearing a gradually applied tensile stress of at least 20 tons on the inch, before rupture, with a reduction of sectional area at point of rupture of not less than 20 per cent.

Washers or small plates of wrought-iron, either round or square, should be used between the timber and the head or nut of a bolt to prevent any crippling of the fibres of the wood. These washers should be about three and a half times the diameter of the bolt for fir, and about two and a half times for oak.

In Figs. 124, 130, and 131, which represent joints for lengthening ties, the bolts are subjected chiefly to shearing stress.

In Fig. 163 a bolt is used to suspend a tie-beam from a queen-post, and is screwed up by means of a nut let into a mortise hole sunk for that purpose in the foot of the queen.

In Fig. 135 a bolt is used in a similar manner to connect two pieces of timber together, end to end. To allow of screwing the nut up, either holes or notches are cut round its outer edge.

In Fig. 169 *b* shows a simpler arrangement than the last, the nut for tightening the joint up being screwed up on the outside.

In Fig. 170, instead of a nut, a wedged key or cotter is used, which can be rapidly taken out should it be required to undo the joint.

When a bolt passes obliquely through a beam, the timber must

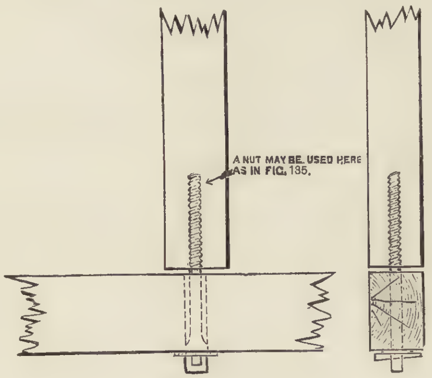


Fig. 170.

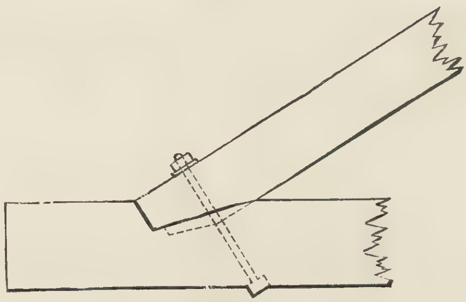


Fig. 171.

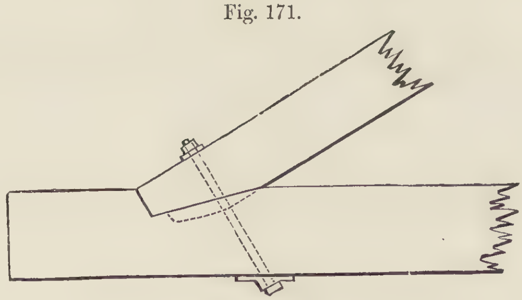


Fig 172.

either be notched, as shown in Fig. 171, so as to present a bearing surface at right angles to the direction of the bolt, or a bevelled iron-washer or *check-plate* must be used for that purpose, as shown in Fig. 172.

The ordinary proportions for bolts, nuts, and washers used in carpentry are as follows:—

	Diameter of bolt being 1.
Diameter of head and nut, if round, or from side to side, if square, hexagonal, etc.	$= 1\frac{3}{4}$
Thickness of head	$= \frac{3}{4}$
Depth of nut	$= 1$
Thickness of washer	$= \frac{3}{4}$
Diameter of washer	$= 3\frac{1}{2}$

The depth of the thread should equal one-tenth, and the pitch one-fifth the internal diameter.

As an extra precaution against stripping the thread, two nuts are sometimes used at the end of a screw bolt. For a table of weights of bolt-heads, nuts and washers, see Hurst's *Handbook.*

Fastenings exposed chiefly to Tension.

Iron Straps.—Iron straps of different kinds are used for connecting timbers together, as shown in Figs. 124, 125, 130, 131, 157, 159, 160, 162, 164, 169, 173, 174, and 175. They

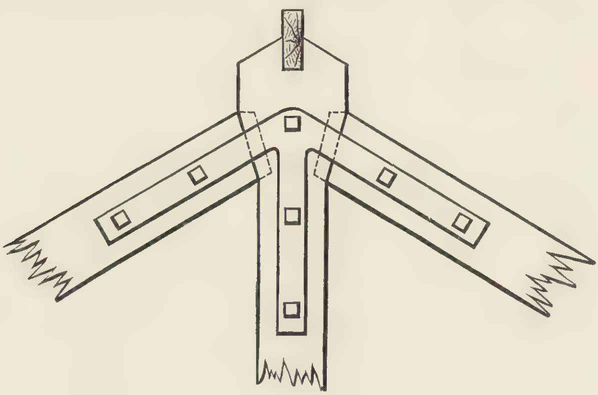


Fig. 173.

do not necessitate so much cutting away of the timber, as is the case with bolts. Care should be taken that they are properly proportioned for the work they have to do.

Stirrup Irons.—Iron straps, such as those used to suspend tie-beams to the feet of king or queen-posts in roof-trusses, are called *stirrup irons.* Fig. 176 is the best form of stirrup iron for such purposes. The sides of the stirrup are kept close against the

wood by means of the gibs *a a*, whilst the wedged keys or cotters *b b* allow of the joint being tightened up after the wood has

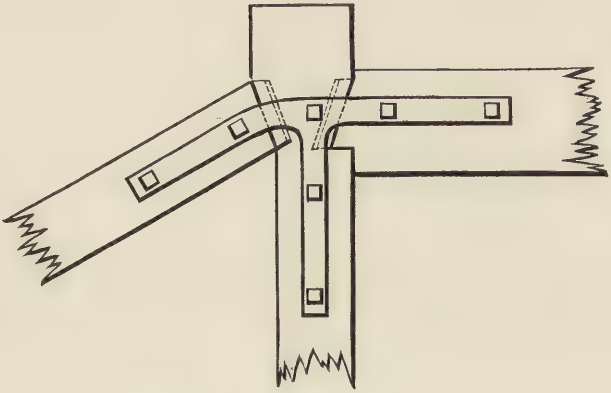


Fig. 174.

shrunk. A is a section of the joint before, and B after tightening up.

Fig. 162 is also a good form of stirrup iron; the lower part, admitting of tightening up, is made with a connecting plate as in Fig. 177. The upper part is secured by a bolt passing through the king-post.

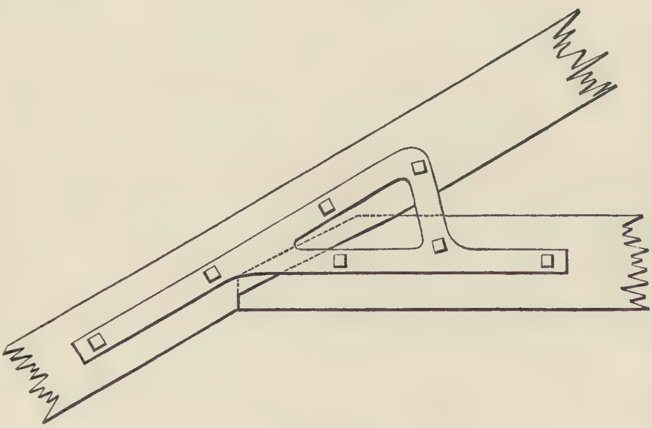


Fig. 175.

The stirrup shown in Fig. 164 is not of so good a form, as it does not admit of being tightened, except by means of the thin wedges shown at *e*.

Heel Straps.—Heel straps are used to secure the feet of struts butting against other timbers in an oblique direction. That shown in Figs. 157, 161, and 177 is one of the best forms, as it

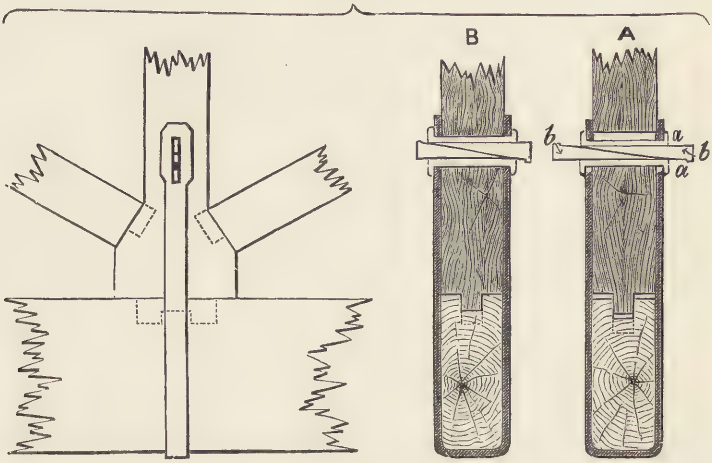


Fig. 176.

admits of being readily tightened up, and is generally used for securing the feet of the principals in wooden roof-trusses. A cast-iron check-plate, similar to that shown in Fig. 157, may with advantage be used to give a square bearing to the strap on the underside of the tie-beam, instead of cutting away the wood, as in Fig. 161, whilst a hardwood or iron wedge is sometimes used with the same object between the heel strap and the back of the principal rafter, which also affords a means of tightening up.

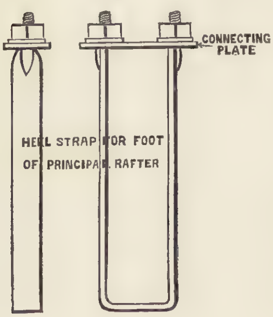


Fig. 177.

The heelstrap, as already stated, should be placed at an angle as oblique as possible to the direction of the rafter, as shown in Figs. 157 and 159, if it is intended to take the thrust of the rafter; and at right angles to its direction, as shown in Fig. 161, if only intended to keep the surfaces of a joint together. In Fig. 159 the heel strap being placed very obliquely, it is bolted through, instead of passing right round the tie beam.

Both heel straps and stirrup irons are often made unnecessarily

heavy. For ordinary work they need not exceed $\frac{3}{16}$ to $\frac{1}{4}$ inch thick by $1\frac{1}{2}$ to 2 inches broad, which leaves a large margin of strength for possible loss of section by corrosion.

Iron Tie-rods.—Iron tie-rods may be used with advantage in all those parts of a wooden truss which are merely exposed to tension. They may be connected with the timbers of the frame by means of screws and nuts, eyes and bolts, slots and wedges, stirrups or shoes, as in Fig. 165, and should in all cases be capable of being tightened up.

Iron Strap Bolts.—These are wrought-iron straps, as shown in Fig. 177*a*, with screw-bolt ends passing through one of the members to be secured together; they allow of tightening up by screwing up the nuts.

Fig. 177*a*.

Fastenings exposed chiefly to Thrust.

Iron Shoes and Sockets.—The ends of posts or struts are often taken by cast or wrought-iron *shoes*, as shown in Figs. 160 and 165, where they are fitted to the heads and feet of king and queen-rods, and to the foot of a principal rafter. Such shoes must be designed for the particular work they have to do, and the sizes of the timbers to be fitted into them.

Preservation of Iron Fastenings.

Iron fastenings, unless protected from the air, rust rapidly; they should never be in contact with unseasoned oak, the gallic acid in which eats away the iron.

Some of the best means of protecting wrought-iron from

oxidation are given on pages 215, 216, to which may be added coating with zinc and with black oxide of iron.

In coating with zinc, called *galvanising*, the zinc is liable to be eaten away by the sulphuric acid in the atmosphere where much coal is burnt, or by the muriatic acid in sea-air.

The Bower-Barff process of covering the surface with an indestructible coating of black oxide of iron, by exposing it to superheated steam or air, is as yet in its infancy, but promises well.

Timber built-up Beams.

In the present day, for all large works, iron would be used instead of built-up wooden beams, except under peculiar circumstances of time and place; hence there is no necessity to enter into the subject here, beyond saying that in many cases a beam of timber cut down the centre and bolted together, with the two halves turned end for end and hearts outwards, will give greater strength than the original beam, as some parts of the beam may be much sounder than others, in which case, by halving it and reversing one of the pieces, the sounder parts will be more equally distributed through the whole length of the beam.

Flitched Beams.—To add to the stiffness and strength of a beam treated as above, a wrought-iron plate, which may be half an inch thick or more, called a *flitch*, is often bolted in between the two halves, or between two deals or planks, as the case may be, and in some cases similar plates are bolted on both sides of a piece of timber. The results of experiments made at the Royal Arsenal to ascertain the relative strength of similar beams, with and without the addition of iron flitches, are given in Hurst's *Edition of Tredgold.*

Ribs for Roofs, etc.—Attention is specially directed to the timber built-up ribs (on the principle of Philebert de l'Orme), shown in the model and drawing of the Rifle Volunteer Drill Shed, Newcastle-on-Tyne, in the R. E. Institute.

The roofs over the galleries leading right and left from the Albert Hall, South Kensington, through the conservatory, to the Exhibition buildings, are also constructed in a similar way, as well as the roofs over many of the temporary Exhibition buildings in the Horticultural Gardens, the ribs being built up of three 1 or $\frac{3}{4}$ inch rough deals spiked together, and

breaking joint. This is a cheap and effective method of construction, capable of more general application than has yet been given to it.

For further information on the subject of built-up beams, see Tredgold *on Carpentry*, and Rankine's *Civil Engineering*, Fifth Edition, p. 463.

Valuing Carpenter's Work.

Carpenter's work is valued by the foot cube when over 3 inches thick, the full length of all the timbers being taken, including the tenons, etc. Under 3 inches thick, it is valued by the foot super; and large surfaces, such as roof boarding, etc., by the square of 100 feet super.

The price depends on the nature of the wood, its scantlings, and the amount of work on it.

Timber Fixed.—The stuff may be either *rough* or *wrought* (planed smooth), and may be put together with glue, spikes, nails, treenails, and rough joints made with the saw; in which case, when over 3 inches thick, it is paid for as *timber fixed.* The term *fixed* also includes all rough joints made when fixing timbers in position, such as by *lapping, notching, bevel,* and *birds-mouth cuttings;* and also *halving* and *dovetailing* in the case of bond timbers, plates, lintels, sleepers, floor and ceiling joists, hip and common rafters, purlins and girders.

Timber Framed.—When a mortise and tenon, or any joint necessitating the use of the chisel, is used, except in the cases mentioned above, it will come under the head of *framed work,* and be paid for at a higher rate. Framed work is mostly prepared for fixing in the workshop, and should strictly be termed "framed and fixed," as the fixing is generally included in the price of framing.

The prices in the War Department Schedule, for both fixed and framed work, include all labour, tools, carriage, tackle and machinery to hoist, fit, place and fix the same, exclusive of any digging which may be required.

Finished Work.—In measuring finished work $\frac{1}{16}$ of an inch is allowed, beyond the actual dimensions, for each wrought face; thus, a 4 by 4 inch scantling, wrought on all four faces, need not measure over $3\frac{7}{8}$ by $3\frac{7}{8}$ inches.

The material itself must be measured up first, and any extra work, such as sinkings, mouldings, rebates, etc., must be measured and paid for separately, at the rates for the same, taken from the War Department Schedules for the district, or from any other reliable source, such as lists of current prices, Laxton's, Atchley's, or Kelly's *Price Books*, etc.; always making an allowance for any difference between the cost of labour in that particular district, and in London, or any other place for which the prices have been framed.

In some cases, instead of taking the extra work separately, it is simpler to add to the price per foot cube or super the cost of the extra work upon it, and then to value the whole at the price per foot, so found; but to do this satisfactorily, the extra work must be uniformly distributed over the whole.

Constants of Labour.—The constants of labour given in Hurst's *Handbook*, or elsewhere, may often be used with advantage, as has already been fully explained in the notes on the valuation of "Bricklayer's Work."

Attention is directed to a mass of valuable information under this head given in an "Analysis of Prices for Schedules of Contract for Engineering and Building Works, carried on under the War Department," which has been issued to the different districts.

JOINER.

After a house has been built and covered in, the joiner takes in hand all the woodwork connected with both its external and internal decoration and fittings, such as the *floors, skirtings, dados, panelled partitions, doors, windows, stairs, cupboards,* etc.

In joiner's work close-fitting joints and smooth surfaces are the chief objects in view, whereas the whole aim of the carpenter is to give strength to resist the strains to which his work may be exposed. Hence, while the latter deals chiefly with heavy framework, and timber in the rough, the former uses smaller pieces of finer and more carefully seasoned woods, joining and fitting them with the greatest accuracy. His work has therefore to be done with much more care, and to a higher degree of finish, than that of the carpenter; all the surfaces left exposed to view are *wrought*, or worked smooth with the plane, ready for painting,

varnishing, or polishing, as the case may be; it is mostly brought ready prepared from his workshop, and only fitted up on the spot.

In designing and executing joiner's work, the greatest care must be taken to fit and frame the different parts together, that they may be affected as little as possible by the shrinking of the wood or its tendency to warp; for however well seasoned wood may be, it is sure to shrink across the grain when exposed to the warm dry atmosphere of a living room, as well as to warp when in thin pieces and not properly secured. For this reason boards of narrow widths are always to be preferred to wider ones, as the shrinking is then distributed over a large number of joints, and is therefore less perceptible. Split panels and open joints soon betray the bad joiner.

The wood, or *stuff*, as it is called, used by the joiner, is chiefly yellow and white deals from the Baltic, and yellow pine and spruce deals from America, besides other woods for special purposes.

American yellow deal is the easiest wood he has to work, from its straightness of grain and freedom from knots, but should only be used where not exposed to the weather. American red pine is, for the same reason, better for the joiner's purposes than Baltic fir.

Joiner's Tools.

The joiner's tools, as authorised for the use of a Company of Royal Engineers, are to be seen on the walls of the Royal Engineers' Institute.

Joiner's work is for the most part prepared, ready for fixing, at the *bench*, which is a wooden table furnished with a *side-board* and *bench screw*, for securing the stuff to be operated on.

The principal cutting tools used by the joiner are *saws*, *planes*, and *chisels*.

Saws.—The saws are known by different names, as follows:—

The *ripper*, which has eight teeth in 3 inches; and *half-ripper*, with three teeth to the inch, both used for ripping wood with the grain only.

The *hand saw*, with fifteen teeth to 4 inches.

The *panel saw*, with six teeth to the inch.

The *tenon saw*, with about eight teeth to the inch, and

strengthened with iron at the back to keep it from buckling; used for cutting tenons.

The *sash saw*, with thirteen teeth to the inch; and strengthened with brass instead of iron at the back.

The *dovetail saw*, with fifteen teeth to the inch; and a large saw with eleven teeth to the inch, called a *carcase saw.*

The *turning* or *compass saw* for circular work, the *key-hole saw* for cutting small holes, and the *bow saw;* all with very thin narrow blades.

Planes.—The planes used by the joiner are of many kinds—

The *bench planes*, as they are called, are the *jack plane*, about 18 inches long, known by the shape of the handle, and used for taking off the rough; the *trying plane*, about 22 inches long, used after the jack plane, for *trying up* surfacework, taking shavings off the whole length of the stuff, instead of stopping at each arm's length, as with the jack plane; the *long plane*, 2 feet 3 inches long, for trying up very true; the *jointer*, 2 feet 6 inches long, used for *shooting* or planing the edges of boards true, in the same way as the trying plane is used for facework; the *smoothing plane*, $7\frac{1}{2}$ inches long, used for cleaning off finished work. For smoothing down wide surfaces, as in panels, a *panel plane* is used, with a broader iron than any of the others, and rather shorter than the *jack plane.*

Rebate planes of different kinds ($\frac{1}{2}$, $\frac{3}{4}$, and $1\frac{1}{4}$ inch) are used for sinking rebates (also called rabbets, which is a corruption of the term) as in Fig. 178; amongst these are the *side fillisters* and *sash fillister*, the latter for running the rebates on sash bars, to receive the glass.

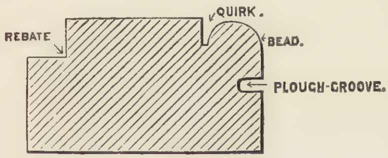


Fig. 178.

Moulding planes, hollows, and *rounds*, for running or *sticking* moulding, as it is called, along a piece of wood.

The *plough*, with set of eight irons, $\frac{1}{8}$ to $\frac{5}{8}$ inch wide, for running *plough grooves* to receive tongues, see Fig. 178.

The *bead plane*, with set irons, for *sticking* beads, as in Fig. 178.

The *snipe bill*, right and left, for forming quirks, as in Fig. 178.

The *compass plane* and the *forkstaff plane*, for forming concave and convex cylindrical surfaces.

The cutting tools used by the joiner are mostly the following kinds of *chisels*, either used with the hand only, or by striking with a wooden *mallet*.

Chisels.—*Firmer chisels*, including *sash* and *paring chisels*, from $\frac{1}{8}$ to 2 inches broad, used with the hand only; *socket chisels*, from 1 to $1\frac{1}{2}$ inch, so called from the wooden handle fitting into an iron socket; *mortise chisels*, with a very thick blade, for cutting mortise holes; *gouges* or *curved chisels; plugging chisels* for cutting into walls; and *cold chisels* for cutting metal.

Boring Tools, etc.—The principal boring tools are the *gimlet* (spike gimlets from $\frac{1}{4}$ to $\frac{3}{8}$ inch, and smaller gimlets of sizes), *brad-awls*, and *stock* or *brace* and *bit;* the latter gives great power for boring holes, driving screws, etc., the *stock* being fitted with bits of different kinds, of which there are about thirty-four in a set.

Amongst the other tools used are the *hatchet, adze, hammer, mallet, screw-driver, pinchers, punch, rasp.*

For setting out and fixing his work the joiner uses a *pencil, chalk-line* and *reel, two-foot rule, compasses, straight edge, steel blades, squares* (6 and 12 inches), *bevel* with shifting blade, *mitre, bevel* or *mitre square, level, plumb-rule, gauge* for drawing lines parallel to one of the edges of a piece of stuff; *mortise gauge*, for marking out the parallel cheeks of the mortise; *mitre box* and *mitre block*, for cutting deep and thin pieces of stuff to a mitre or angle of 45° to one of their sides; *shooting board*, for holding the stuff when *shooting* or planing the edges; *donkey's ear*, which serves as a guide for sawing the end of a piece of stuff to a mitre; *mitre shoot* or guide to work to when cleaning up a mitre after sawing; *old woman's tooth*, for cleaning out grooves; besides *cylinders, templets, moulds, cramp iron* and *flooring cramp* for tightening or screwing up his work, *glue pot* and *brush, oil stone* and *can, saw files*, 3, 4, and 5 inches, *saw set, saw block*, etc.

Valuation of Joiner's Work.

Joiner's work is paid for by the foot super, or by the *square* of 100 feet super, in the case of large surfaces, and narrow widths by the foot run or 10 feet run.

Glue is always included, but screws and *driving* are paid for extra.

In measuring up joiner's as well as carpenter's work, $\frac{1}{16}$ of an inch must be allowed for each wrought face. Thus a 2-inch door

will not actually measure more than $1\frac{7}{8}$ inch when finished ready for painting.

Operations in Joinery.

The principal operations in joinery consist of *sawing, planing, rebating, grooving, chamfering, bevelling, scribing, keying,* and *clamping;* executing *mouldings, joints* of different kinds, *circular work, ledged work,* and *framed work.*

Rebating, Chamfering and Bevelling.

Fig. 179 shows a rebated, a bevelled, a chamfered, and a stop chamfered edge.

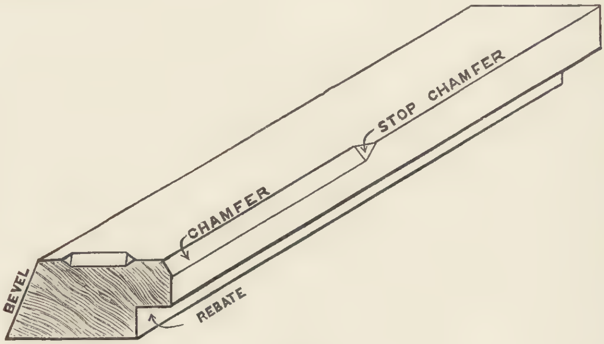


Fig. 179.

All stops to chamfers, rebates, etc., have to be paid for at so much each for the extra trouble of having to stop the plane and work by hand, or hand-work it altogether—when cut with the chisel it is said to be hand-worked—instead of running the plane right through the whole length of the stuff.

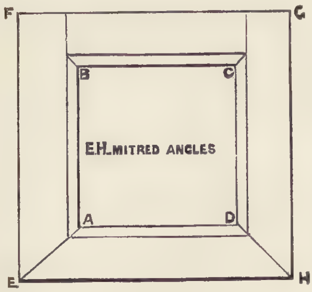


Fig. 180.

A chamfer, rebate, bead, groove, or similar work run with a plane along the inner edge of a piece of framework, as round A B C D, Fig. 180, must always be measured by girthing the outer edge, as it had to be run from end to end of each piece of stuff, before the pieces were framed together.

Scribing.

This is the operation of bringing the edge of one piece of wood to fit close up to an irregular surface. Thus, in the wooden skirting round a room, not only in the first fixing, but often when, from the sagging of the floors or the shrinking of the wood a gap is left between the bottom edge of the skirting and the floor, it has to be *scribed,* or made to fit down to the floor line; this is done as follows:—The skirting having been placed in position with its upper edge to a true line, a pair of strong compasses is taken and opened to the greatest distance that the lower edge of the skirting is anywhere distant from the floor. One point of the compass is then drawn along the floor, whilst the other point is made to scratch a line on the face of the skirting, which line will, of course, be exactly parallel to the floor line; and to this line the lower edge of the skirting must be truly worked down.

Keying and Clamping.

A broad and thin piece of wood is sure to twist and warp in drying, or from alterations in the hygrometric state of the atmosphere, therefore it is advisable—especially in such cases as the panelling round a room, against an outer wall in any way exposed to damp—to guard against any warping by keying the panels. This is done, as may be seen in Fig. 181, by fixing a piece of wood, called a key, in a dovetailed groove run at the back of the board, at right angles to the grain of the wood, the key being thick, and the grain in the direction of its length.

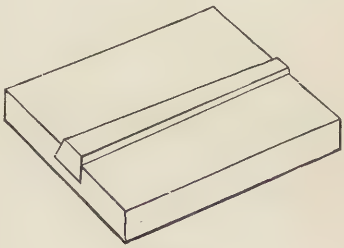


Fig. 181.

Such a key is also used at the back of boards made up of two or more narrow pieces placed side by side, to hold them together in one plane. The key is feathered, or made broader at one end than the other, to allow of its being driven tightly, as well as to permit of the free expansion and contraction of the wood.

Clamping is done with the same object as keying, a piece of wood called a clamp being fixed across the end grain of a board

to keep it from twisting. Mortise holes are cut in the clamp, and tenons along the edge of the board, as shown in Fig. 182.

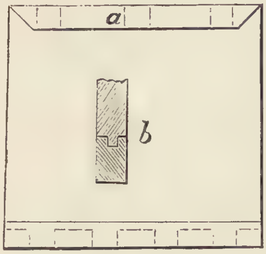


Fig. 182.

The end marked *a* is *mitre clamped* for appearance sake. Good drawing-boards are both keyed and clamped. The clamp should also be grooved, and the tenons formed with a *haunching* to fit into the groove in the clamp, as seen at the bottom of Fig. 182, and in end elevation at *b*.

Mouldings.

Moulding, in joiner's work, is cutting or planing down the surface of the wood to different curves, etc.

When mouldings are run with moulding planes on the woodwork to be ornamented, they are said to be *stuck;* and when made with chisels instead of planes, they are said to be *hand-worked.*

When mouldings, made on separate pieces of stuff, are fixed on to the woodwork to be ornamented, they are said to be *laid in* or *planted.*

Running mouldings, of almost every description, are now made by machinery, and may be bought by the 10 or 100 feet run

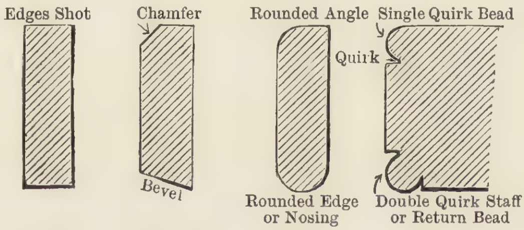


Fig. 183. Fig. 184. Fig. 185. Fig. 186.

at a far cheaper rate than they can be turned out at the bench; therefore it is usual to *plant* the mouldings on woodwork, instead of *sticking* them in the solid.

In measuring up joiner's work, mouldings over $2\frac{1}{2}$-inch girth are generally taken by the foot super.

A number of simple curves and mouldings are in constant use for *planting* on joiner's work. Those in most common use are given in Figs. 183 to 202, starting from a square edge, as they appear naturally to follow each other.

It will be seen from Figs. 186, 187, 188, and 189, that the difference between a *torus* and a *bead* in joinery is that a *fillet*

Fig. 187.

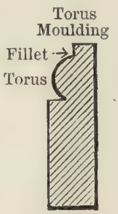


Fig. 188.

Fig. 189.

(fillets are narrow plane surfaces used for separating and terminating mouldings) adjoins one edge of a torus, whereas there is none in case of a bead.

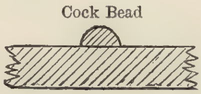


Fig. 190.

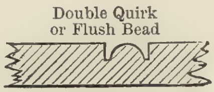


Fig. 191.

Fig. 192.

Fig. 193.

The mouldings shown in Figs. 190, 191, 192 and 193 are used to ornament either flat or curved surfaces of woodwork, the other mouldings given are applicable to the edges of boards, etc.

Fig. 194.

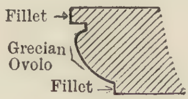


Fig. 195.

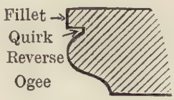


Fig. 196.

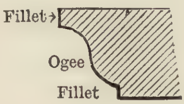


Fig. 197.

Fig. 198.

Running *ogee* and *ovolo* mouldings, combined with quirks, beads,

etc., as shown in Figs. 199 and 200, are those in most common use for planting on joiner's work.

When, at the juncture of a panel with the framing, mouldings are used which project beyond the face of the framing, as in Fig. 201, they are called *bolection mouldings.*

Fig. 199.

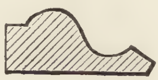


Fig. 200.

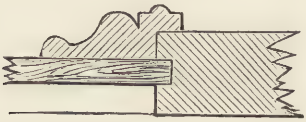


Fig. 201.

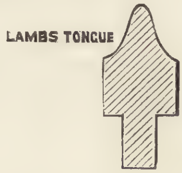


Fig. 202.

Fig. 202 is a section of a sash-bar, with what is called a *lamb's-tongue* moulding.

The above mouldings, though in every day use by modern joiners, are not recommended for their beauty. When good mouldings are required they must be specially designed for the position they are to occupy, always bearing in mind that the play of light and shade over their hollows and projections is what gives effect to their different forms, and therefore the direction from which the light falls upon them, and the point of view from which they will be seen, must in all cases be taken into consideration.

Numberless mouldings of different kinds may be found in works on joinery, such as Newland's *Carpenters' and Joiners' Assistant,* Tredgold, etc.; whilst pattern books giving endless sections of mouldings turned out by machinery can be obtained from any Steam Joinery Works.

Joints in Joinery.

Joints in joinery may be divided into—I. Meeting Joints. II. Connecting Joints.

MEETING JOINTS.—The joints included under the head *meeting joints* are such as are used to guard against open joints consequent on the shrinking of the wood, as distinct from those which are formed for the purpose of holding the different parts together.

Edges Shot.—When boards are placed side by side, the edges

may be merely shot square—the process of planing their edges true being called *shooting*—and butted against each other, as at A, Fig. 203; in which case the boards in shrinking will leave an open joint, admitting light, air, and dust.

Fig. 203.

In order to prevent open joints, one of the joints shown at B, C, D, E, F, G, may be used.

Rebating, Ploughing, and Tongueing.—The joint B, Fig. 203, is *rebated*, and beaded on one face, the bead being usually added with the idea of converting the joint into an ornamental feature, and disguising any little shrinkage which would otherwise be an eyesore; but which, with a bead, only gives the appearance of a little wider quirk. This joint is also sometimes called a *fillistered* joint.

When a bold bead is used with a rebated joint, it is liable, if the board be thin, to weaken the projecting edges of the rebate, when placed as at B; in such cases the bead should be placed, as at G, on the solid part of the wood.

The joint C, Fig. 203, is *grooved* and *tongued*, and beaded on the lower side, a plough groove being run along the edge of one board, and a corresponding tongue, to fit into it, along the edge of the other. Boarding put together in this way is called *match-boarding*.

The joint D, Fig. 203, was, and is still, used in mediæval work; the tongue running to a point is less liable to break off, and weakens the edge of the other board less. Chamfers, as shown on the lower side at D, are used to emphasise the joints, instead of beads.

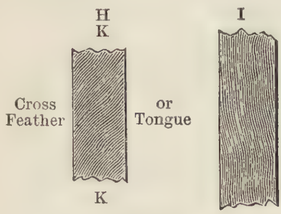


Fig. 204.

Both B, C, and D are wasteful of material, as they reduce the width of each board, which is not the case with F or with the *ploughed* and *tongued* joint E, in which a plough groove is run along the edge of each board, and a separate slip of wood, called a *tongue*, is fitted into the grooves.

The tongue may be of wood or hoop iron; the latter gives strength without weakening the edges of the boards so much, the plough groove required being much narrower. If of wood,

much greater strength is obtained by using a *cross* or *feather tongue,* in which the grain runs at an angle to, as at H, Fig. 204, instead of in the direction of its length, as at I, making it much harder to break along K K.

Rebating and Filleting.—The joint F, Fig. 203, is *rebated* and *filleted,* and, though not applicable to joints seen on both faces, is much used in laying floor boards; like that at E, it does not reduce the breadth of the boards, whilst it effectually closes the joint. In this case, rebates are run along the edges of the board, and plain wooden slips or fillets fitted into them.

Mitres.—When the edges of two boards meet at an angle, one of the joints in Fig. 205 is used, the first five of which are

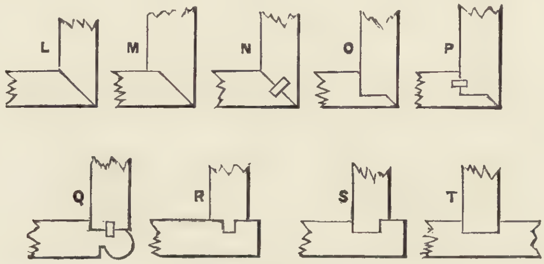


Fig. 205.

mitred joints suitable for salient angles, or, when seen, as both salient and re-entering angles.

The joint M is similar to L, except in the two pieces being of different thicknesses. At N a tongue is used to close the joint more effectually.

The joints O, P, can be securely nailed from both faces, that at P being closed by a tongue, as at N.

At Q a plain joint is made, with or without a tongue, and a staff bead is added at the angle.

The joints R and S are tongued and grooved, and are used in cases where the re-entering angle alone is visible, as in skirtings in the corner of a room.

At T the entire end of one piece is *housed,* or let into the face of the other, which is done when both re-entering angles are seen, and also when strength is required, as in housing the ends of treads and risers into the strings of stairs.

Connecting Joints.—The chief joints used in connecting or

framing joiner's work together are the *mortise* and *tenon* and *dovetailing.*

Mortise and Tenon.—Mortising and tenoning is similar to the same operation in carpenter's work, except that it has to be done with greater care and neatness.

The thickness of the tenon is made about one-fourth the thickness of the stuff, and its breadth not more than five times its own thickness; for a broad tenon would shrink considerably and get loose, besides necessitating a wide mortise, which might weaken the framing too much. Accordingly, when the wood is wide—generally if over 7 inches wide—a double tenon should be used, as in Fig. 206. The mortise holes are cut slightly wider at the outside, to allow of wedges being driven in to grip the tenon, glue being used as a further security.

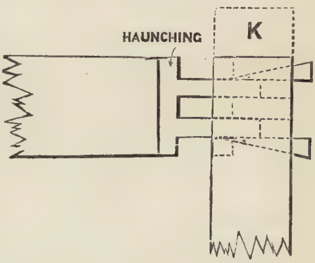


Fig. 206.

As the mortise holes should not be cut too near the end of a piece of wood, as in the stile of a door, the stile is not cut down to its proper length at first, but is left with a horn, as shown by dotted lines at K, until the framing is completed, in order to guard against splitting the ends in cutting the mortise and driving the wedges; in addition to which the tenon must be set back from the upper edge of the rail to keep the upper mortise from cutting away too much of the top of the stile. To clamp the rail, and give it a better hold on the stile, a short tenon, called the *haunching*, is worked out of the shoulder, which cuts into the stile but little, whilst, by preventing any warping of the rail, it keeps the surfaces of the rail and stile in the same plane. In panelled work the depth of the haunching is regulated by the depth of the groove for the panels, which is run straight through the whole length of the stile. When the stuff is thick, the tenon at the end, if cut to one-fourth of its thickness, would necessitate too wide a mortise hole; in such cases the main tenon may be made thinner, and a short *stump-tenon* added on each side of it, as in Fig. 207, which will greatly strengthen the joint, without necessitating the cutting of any large mortises.

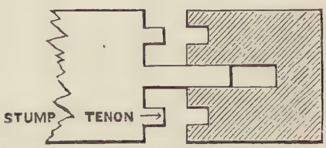


Fig. 207.

In mediæval joiner's work, as also in modern French joinery, the tenons are secured in their places by means of wooden pins, which should be of hardwood, driven through the cheeks of the mortise, the pins being slightly tapered, and the holes cut, as in Fig. 208, so as to draw the joint up tight in driving them through. This is done by means of iron *draw-pins,* especially in heavy work, in which the point of a wooden pin would be liable to break; the iron pin is then withdrawn and the wooden pin inserted. The wedges used in modern English joinery are more secure—pins are only used in carpentry and for common joinery—for the wooden pins are apt to shrink in their diameter and get loose, and the framing to shrink in its thickness, leaving the pins projecting beyond the face of the work, since they will not shorten in the length of the grain.

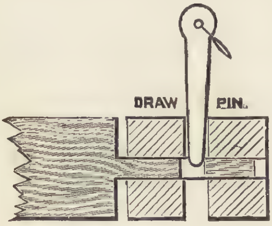


Fig. 208.

Dovetailing.—Figs. 209 and 210 are dovetailed joints suitable for re-entering angles in joiner's work.

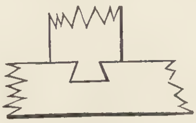


Fig. 209.

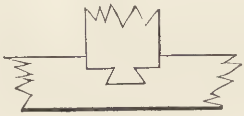


Fig. 210.

There are three different kinds of dovetails, specially applicable to mitred joints—viz. the *common dovetail* (Fig. 211), the *lapped dovetail* (Fig. 212), and the *secret or mitred dovetail* (Fig. 213).

The *common dovetail* is the strongest, but shows the ends of the dovetails on both faces of the angles, and is therefore only used in such places as the back of a drawer, where the external angle is not seen.

The *lapped dovetail,* where the ends of the dovetails show on one side of the angle only, is used in such places as the front of a drawer, the side being only seen when opened.

In the *mitred* or *secret dovetail* the dovetails are not seen at all. It is the weakest of the three kinds.

Glued Joints.—Dovetail keys, as shown in Fig. 214, are used to hold pieces of wood together; also tongues, as in a ploughed

and tongued joint, or wooden pins or dowels, as shown in Fig. 215, glue being used to give them a hold.

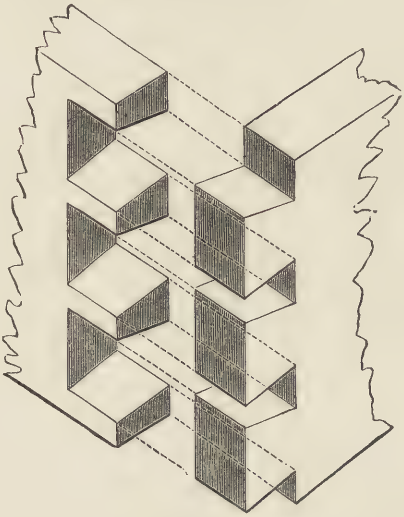


Fig. 211.

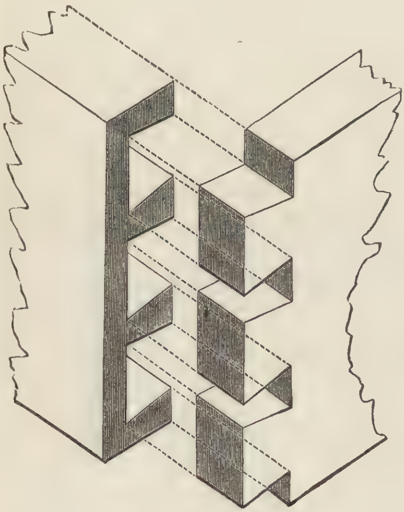


Fig. 212.

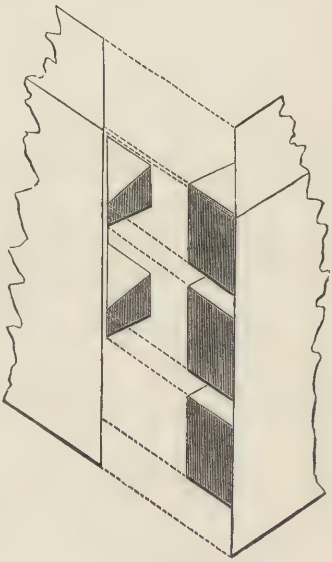


Fig. 213.

Glue is also used by itself to connect the plain surfaces of joints together.

Glued and Blocked.—When it is required to keep two pieces of wood true to any particular angle, blocks of wood, cut to the required angle, may be glued in the re-entering angle, as in Figs.

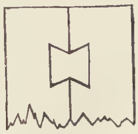


Fig. 214.

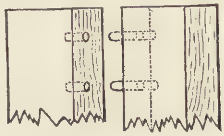


Fig. 215.

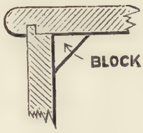


Fig. 216.

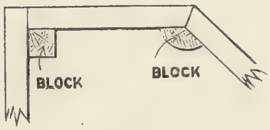


Fig. 217.

216 and 217. The former represents in section the riser of a stair, tongued and grooved to the underside of the tread, with blocks glued into the angles, to keep the pieces square to each other; such work is said to be *glued* and *blocked.*

Circular Work.

Circular, curved, or *sweep* work, as it is called, may be brought to the required form in different ways, according to the nature of the work. It may be curved round the edge and flat on face, as in the top of a round table; curved on face, as in the wooden casing of a column or the curved linings to a circular door or window head; or it may be curved as in the case of ribs.

Glued up in Widths, Bent in Fixing.—If flat on face, and too large to be cut out of one piece, it may be glued together in widths, with the edges of the pieces merely butting, or, for greater security, ploughed and tongued, or pinned or dowelled, as already described, the outer edge being cut to the required curve; and, if required, a thin veneer bent round, as shown in Fig. 218. Such work should be measured from out to out each way, to allow for trouble and waste in cutting to the curve. The fillet round the outer edge, being bent in fixing, must be charged at one-fourth more than if it were straight.

Fig. 218.

Glued up in Thicknesses.—Circular work may be glued up in thicknesses, thin pieces being bent round a centre mould, as in Fig. 219; in which case it should be measured from out to out, and charged at three times the price of a square surface made up of pieces glued together in widths, as in Fig. 218.

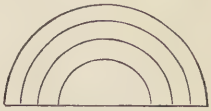


Fig. 219.

Curved on Face and Plan.—Work curved on face, as a hollow wooden column, is glued together in narrow widths, on the same principle as the staves of a cask; and the joints may be further secured by being ploughed and tongued and glued and blocked, the price being about one and a half times the same if straight. In some cases, as in curved panelling, the wood may be steamed and bent to the required curve, the price being about twice that of straight.

Such work as curved ribs may either be cut in one piece out of the solid, if the sweep is not too quick, or two or more short pieces may be cut out of the solid to the required sweep, and then joined end to end, as in Fig. 220, by a mortise and tenon or a lap joint, or by some joint similar to those shown in Figs. 133, 134, and 135.

Ribs may also be curved by steaming a piece of wood, and bending it to the required shape. In both cases the price charged must be about twice the price of the same rib, if straight.

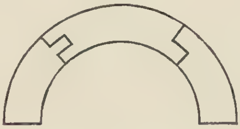


Fig. 220.

Fig. 221.

A curved rib may also be made up of thin pieces bent round a mould and glued together in thicknesses, such work being charged at about three times the price of a solid straight piece of the same scantling.

A piece of wood may even be notched with a saw on one side, as shown in Fig. 221, so as to allow of its being bent round, and afterwards finished off to the required curve; but this is only a rough way of working, and is worth about one and a half times the price of straight.

Ledged Work.

When boards or battens are placed side by side, and other pieces, which are called *ledges*, nailed across to keep them in position, the work is said to be *ledged*. Very common doors, as shown in Fig. 222, as well as common shutters, etc., are put together in this way.

Framed Work.

There are two ways of framing the fittings of a house, such as doors, linings, partitions, and cupboards; they may be either *framed* and *boarded* or *battened*, or *framed* and *panelled*; in both cases the object being to economise material, and gain strength, by making a strong skeleton framework, with the voids filled in with thinner stuff, either in the shape of boards or panels.

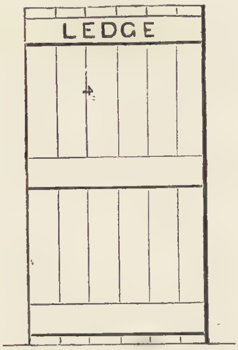


Fig. 222.

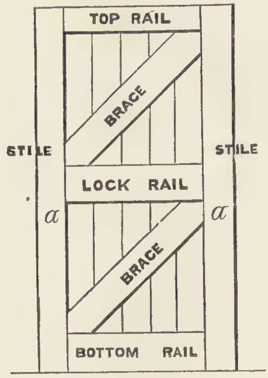


Fig. 223.

Framed and Boarded.—As an instance of framed and boarded or battened work we can take a common and strong form of door, much used in barracks and for yard gates, etc. The framework consists of the upright pieces *a a*, Fig. 223, called *stiles*, which are made the full height of the framework, and the horizontal pieces, called respectively the *top rail*, *lock rail*, and *bottom rail*, framed into the stiles. The rails are made thinner than the stiles, the space between the stiles being filled up with board or battens, which should be either rebated or ploughed and tongued at the joints, and nailed to the rails. The top and bottom rails, or it may be the top rail only, are sometimes made the same thickness

as the stiles, the boards or battens being ploughed and tongued into them, or into the top rail only, as the case may be.

The boarding, in order to reduce the effects of shrinkage to a minimum, as already explained, should be in batten widths.

Diagonal pieces, called *braces*, should also be added to give strength to the framing, in which case it would be *framed, braced,* and *boarded* or *battened.* The lower ends of the braces, in door construction, should be framed into the hanging stiles, and the upper ends into the rails.

Framed and boarded partitions, etc., are constructed on the same principles, with uprights and rails, the boarding being generally nailed to the latter only.

Framed and Panelled.—In framed and panelled work the space contained between the stiles and the top and bottom rails is subdivided into small compartments by means of horizontal rails and short pieces framed vertically in between them, called *muntings* or *mountings;* each void being filled in by a thin piece of boarding called a panel, fitting into plough grooves run round the inner edges of the framework, in which it should not be glued or fixed in any way, but allowed to expand and contract freely, for panels confined at the edges will, in shrinking, split right across. They are clamped and prevented from twisting by those parts of the framing in which the grain of the wood runs across the grain of the panels. Fig. 224 shows a six-panelled door so constructed, in which A A are the stiles, B^1 B^2 B^3 B^4 are the top rail, frieze rail, middle or lock rail, and the bottom rail respectively, C C C are the *mountings* framed in between the rails, and D D D D D D the panels.

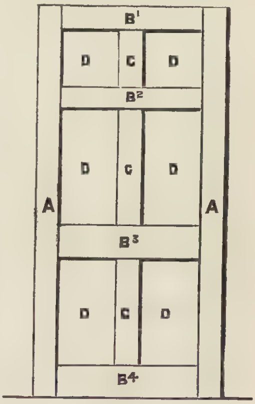


Fig. 224.

When a panel is made up in more than one width, the boards should be glued together with the grain reversed alternately, and no unkeyed panel, as in doors, etc., should exceed 15 inches in width and 4 feet in length.

When the panels are necessarily large, they may be made up of boards or battens ploughed and tongued together at the joints. The battens being often placed diagonally, for appearance sake.

Flat Panels.—The panels may be of one uniform thickness,

fitted round the edges into grooves in the framing, in which case they are called *flat* panels, and are usually about one-third the thickness of the framing, as shown in section at A, Fig. 225 If the edge of the framing is left square, without any moulding, and the panel is flat, it would be described as *framed square and flat.*

A panel as at C, Fig. 225, where a moulding is planted round

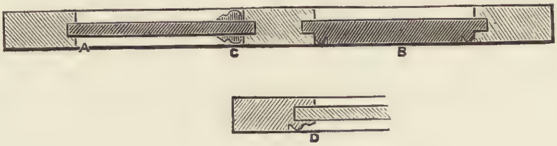


Fig. 225.

the edges of the panel, on both sides, is said to be *square and flat and moulded two sides.*

In all cases of moulded panels the moulding should be *planted* on, and not *stuck* on the stiles and rails, as at D, Fig. 225, in which case the panel is but weakly held in the framing; and by running a knife round the moulding the panel can easily be cut out, which cannot be done when it is planted on, as the knife would be stopped by the nails securing the moulding to the frame.

Flush Panels.—When the face of a panel, as at B, Fig. 225, is brought to the same plane as the face of the framing, it is said to be *flush.* The edges are rebated to form tongues to fit into the grooves in the stiles and rails.

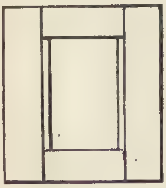


Fig. 226.

Bead Butt.—A flush panel in common work has a bead run along two edges of the panel, with the grain of the wood, stopping or *butting* against the rails at top and bottom, as in Fig. 226. Such work is said to be *framed bead butt.*

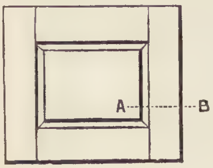


Fig. 227.

Bead Flush.—In work of a rather better kind the bead is continued all round the frame, as in Fig. 227, being either stuck on the stiles and rails, instead of on the panel, or stuck with the grain, on two edges of the panel, and planted across the grain at the top and bottom of the panel, as shown in Fig. 228, which is a section through

Fig. 228.

A B, Fig. 227. Such work is said to be *framed bead flush.* The bead on the panel makes the strongest job, as the edges of the framing, which have to hold the panel, are not weakened, except by the grooving.

Raised Panels.—Raised panels are thicker at the centre than round the edges, where they are bevelled off to the thickness required to allow of their fitting into the grooving in the stiles and rails, as shown in Fig. 229, which represents a *raised moulded* panel, and *square* and *flat* and *moulded* at back. A square sinking, or some simple moulding, generally separates the raised from the sunk surfaces of such panels.

Fig. 229.

Hinged Joints.—All the ordinary hinged joints used by joiners, as well as special joints contrived to fit close, even when the movable part, such as a door, is wide open, are illustrated fully in Newland's *Carpenter's Assistant*, as well as in most works on Carpentry, and therefore need not be enlarged on here.

Fixing Joiner's Work.

Wood Plates and Wood Bricks.—In order to hold the nails or screws used in fixing joiner's work to walls, either wood plates or wood bricks were, up till lately, invariably used. The plates built into brick walls were of the same section as a brick, but in long lengths, and were laid in the face of the wall, wherever long lengths of joiner's work had to be fixed, such as for wooden dados or panelling round rooms, etc.; whilst wood bricks, made the size of the bricks used, were in the same way built into the walls to fix detached pieces of joinery, or at regular vertical intervals, where the work was not in the direction of the courses of brickwork, as in linings to doors and windows. In the present day, however, the practice of building timber into walls is dying out, owing to the danger of spreading fires, the damage to the wall from its being burnt out or rotting, and its shrinking and so losing its hold in the wall.

As a substitute for wood plates and bricks, wood *slips* and *plugs* are used.

Wood Slips.—Wood slips are thin pieces, generally of fir, about $9 \times 3 \times \frac{3}{8}$ inches, or longer if necessary, and should be well seasoned. They are built into the joints at convenient

intervals, and being only just thick enough to hold a nail, they do not shrink sufficiently to allow of their getting loose; besides which, if they rot, or are burnt out, the stability of the wall is not sensibly affected. For securing door and window linings, the slips are usually built in at intervals of from 18 inches to 2 feet. They are generally paid for by the foot run or number, including building into the wall.

Plugging.—In common work small fir wedges or *plugs*, about 2 inches wide, $\frac{1}{2}$-inch thick, and 4 to 5 inches long—just large enough to take a single nail—are driven into the joints of walls, in holes made by cutting out the mortar with a chisel; they are driven at about 1 foot horizontal, and 18 inches to 2 feet vertical intervals, and are paid for at so much per foot run or foot super of the stuff plugged to the walls.

Grounds.—In fixing superior fittings, small fillets or battens of wood, called *backings* or *grounds*, are secured to the walls by one of the above methods. These *grounds* may be either rough or wrought and framed with more or less care, and levelled, so as to present a perfectly true surface to which to fit the finished work; and when fixed are generally used by the plasterer as a guide in running his *screeds*.

Iron Holdfasts.—The backings or grounds may also be secured to walls by iron holdfasts driven into the joints, on alternate sides of the battens, with nail holes in the heads, through which to drive a nail into the batten. Iron holdfasts should always be used in securing woodwork to chimney breasts; and on no account should woodwork of any kind be built into a wall so as to reach within 14 inches of a flue.

Pallete Bricks.—Bricks, Fig. 230, called *pallete bricks*, rebated on edge, so as to hold a $1\frac{1}{2}$-inch fillet securely in the wall—splayed from $\frac{7}{8}$ inch at one edge to $\frac{1}{2}$ inch at the other—have been occasionally used, but are not recommended, as the advantage gained is not to be compared to the extra labour and expense involved.

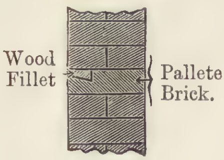


Fig. 230.

Screws and Nuts.—In some cases metal fastenings have been secured in the joints of masonry or brick walls by the ends in the wall being either jagged or turned up, and the outer ends screwed, and of a sufficient length to pass through the wooden fittings, which are then secured by nuts. The nuts can be made ornamental, and

will allow of the woodwork being taken down and refixed, in case of any alterations being made.

Wood Lintels.—Lintels, or pieces of wood spanning the heads of openings, are also used to give a flat straight surface to which to secure the wood linings and other fittings. In brickwork they are usually over small openings, 3 inches thick, or the depth of one course of bricks; from $4\frac{1}{2}$ to 9 inches wide, and should rest about 9 inches in the wall, or the length of one brick, at each end. Over wider openings it is customary to give them a depth of 1 inch to every foot of span. They must always be relieved of the weight of walling above by a discharging arch turned over them; the springings of such arch being quite clear of the ends of the lintel, or wood framing, as the case may be; when this is not attended to, the shrinking, rotting, or burning out of the wood will, if the arch is resting on its ends, lead to its sinking down, together with so much of the wall above as it supports.

It is, however, advisable to avoid the use of wood lintels as much as possible; and in countries where wood is subject to the ravages of insects, such as white ants, no wood whatever should be built into the walls, even in the form of horns to door frames.

Concrete Lintels.—Concrete lintels—about 6 of breeze from gasworks to 1 of Portland cement—are now made, $4\frac{1}{2}$ by 6 inches, or of any convenient section which will allow of a nail being driven into them, and at the same time are as cheap as wood, without being liable to damage by rot or fire, or to getting loose from shrinking. Blocks of the same material might be used as a substitute for wood bricks or slips.

Glueing up.—In securing the joints of framing, as well as for other purposes, glue is indispensable to the joiner. It is obtained by boiling down the horny and sinewy parts of animals, the older they are the stronger being the glue produced. Good glue should be very hard in the cake, and when held up to the light, should be of a transparent yellowish-brown colour, free from cloudy or black spots. It should be broken up in small pieces, and steeped in cold water for twelve hours, and then heated up with a little water until of a uniform consistency, and just thick enough to run freely off a brush in a continuous thin stream, without breaking into drops.

In glueing-up work, the surfaces should be made perfectly clean, smooth, and dry, the glue being applied as hot as possible.

Strength of Glue.—From experiments made by Tredgold the

adhesive force of fresh-made glue, cementing together two pieces of dry ash, after being left for twenty-four hours, was found to be 715 lbs. to the inch, the force being applied gradually, and the surfaces separated being found on examination to be not entirely covered.

With glue which had been frequently melted, with occasional additions of fresh glue and water, the adhesive power was reduced to from 350 to 560 lbs. to the inch. The lateral adhesion of the fibres of a piece of Scotch fir, quite dry and seasoned, was found to be 562 lbs. to the inch, therefore with fresh-made glue the wood would have parted before the glue.

The tensile strength of a square inch of solid glue was found to be 4000 lbs. (*Phil. Mag.*, 1826).

Glues to resist Moisture, etc.—The strength of common glue for coarse work, and to stand the weather, is increased by adding a little finely-powdered chalk.

A glue for outside work is often made by grinding as much white-lead with linseed oil as will just make the liquid of a whitish colour and strong, but not too thick.

Glue dissolved in skimmed milk, in the proportion of 1 lb. of glue to 2 quarts of milk, is said to resist moisture with great effect.

Ordinary glue can be rendered insoluble in water by adding to the water with which it is mixed a small quantity of bichromate of potash; the exact proportion must be ascertained by experiment, but, for most purposes, $\frac{1}{50}$ the amount of glue will be sufficient.

A glue, said to be proof against both fire and water, is made by mixing a handful of quicklime with 4 oz. of linseed oil, boiling to a good thickness, and drying on tin plates in the shade. It is rendered fit for use by boiling over the fire in the usual way.

Marine glue is made of 1 part of india-rubber, 12 of mineral naphtha or coal-tar, gently heated and mixed, to which is added 20 parts of powdered shellac. It is then poured on to a slab to cool, and in using must be heated to about 250°.

IRONMONGERY.

At the end, and forming part of the Carpenter's Schedule, come the sundries of ironmongery, which have to be fixed by the carpenter and joiner, such as door and window *furniture*, etc., comprising bolts, hinges, locks, latches, handles and knobs for

doors and shutters, etc.; door springs, finger plates, shutter and cupboard *turns* or fasteners, sash fasteners, pulleys, lines and weights; besides many other articles, amongst which nails and screws must not be omitted.

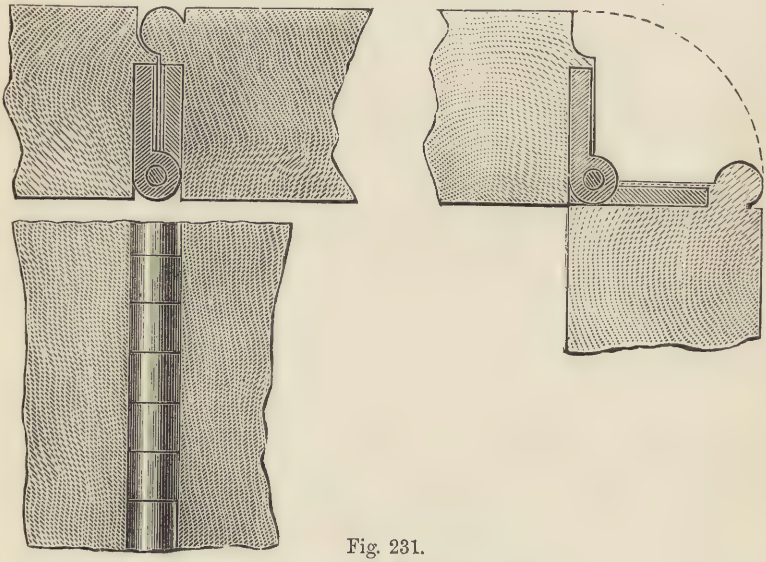


Fig. 231.

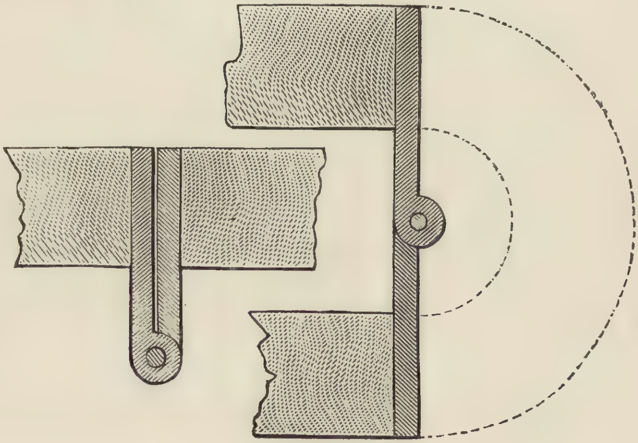


Fig. 232.

Hinges.

The principal kinds of hinges are as follows:—

Butts, Fig. 231; *projecting butts*, Fig. 232, used when a door,

shutter, etc., has to swing clear of a projection, those used for outside shutters, to allow of their swinging clear of the reveals, being called *parliament* hinges; *rising butts,* Fig. 233, which allow of a door fitting close down to the floor when shut, and rising clear of the carpet as it is opened.

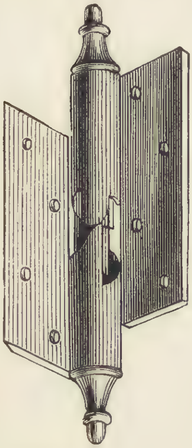


Fig. 233.—Rising Butt.

Back-flap, table, or *shutter* hinges, Fig. 234, which allow of leaves or flaps folding back against each other.

H hinges, HL hinges, and *cross garnet,* also called T or *strap* hinges, Figs. 235-237, used for common work, and in such cases as ledged doors, when the stuff is too thin to admit of butts being screwed on to its edge; or, in the case of HL and T hinges, when it seems desirable to strengthen the points of connection between the rails and the hanging style.

The use of strap hinges as a means of ornamenting as well as strengthening doors, lids,

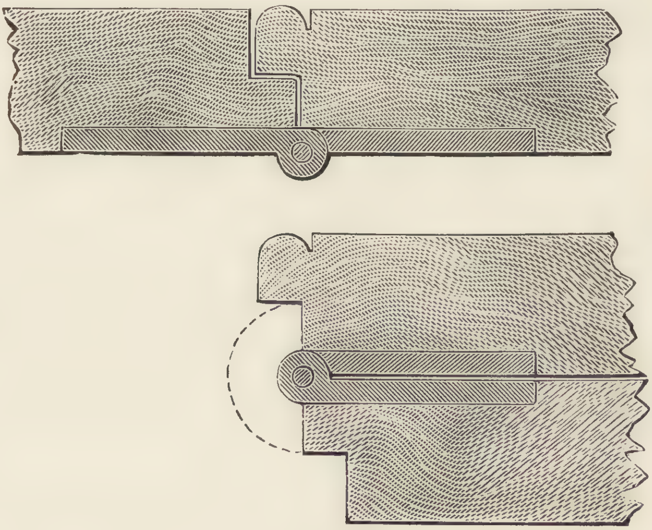


Fig. 234.

etc., is almost entirely confined in this utilitarian age to church and similar work.

Hook and *eye* hinges, Fig. 238, are used for gates and heavy outside doors, as to coach houses, etc.; the hooks being either riveted

to plates or screwed into or right through the frame and secured with nuts, the latter plan being the strongest for heavy work.

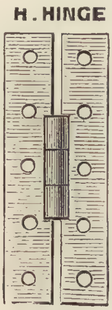


Fig. 235.

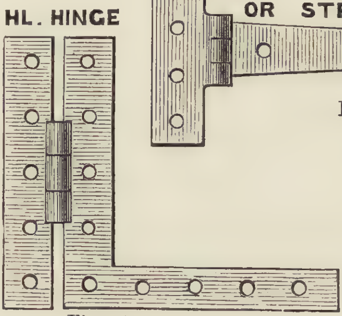


Fig. 236.

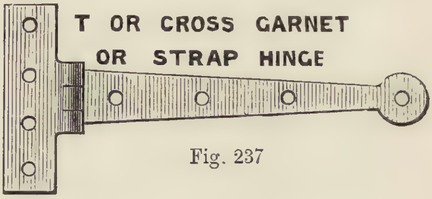


Fig. 237

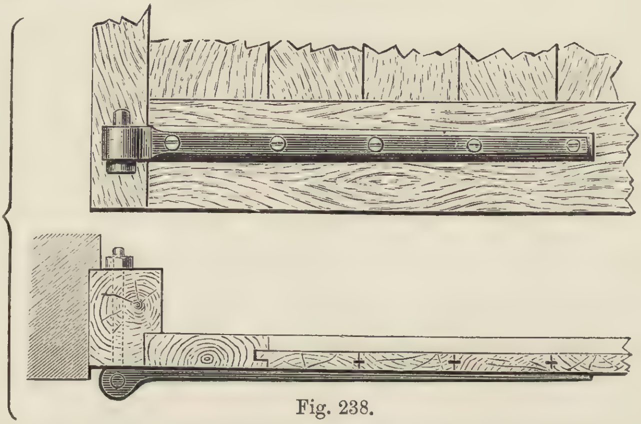


Fig. 238.

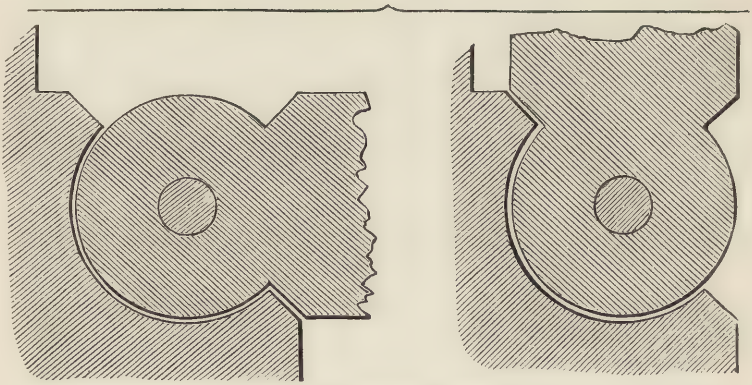


Fig. 239.—Centre-Pin Hinge.

Centre-pin or *centre-point* hinges, Fig. 239, for ruled joints, etc.

Spring hinges, Fig. 240, and *swing centres* of various kinds for self-closing doors, etc.

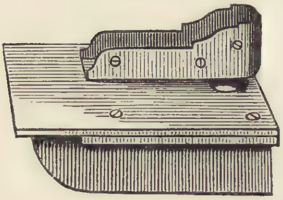


Fig. 240.—Patent Door Spring.

Locks.

The locks ordinarily used for doors may be classed by their outward appearance and method of fixing as *stock locks, rim locks,* and *mortise locks.* These again go by different names, such as the *draw-back lock,* used for street doors, in which the bolt may be locked and unlocked with a key, may be left halfway out—in which position it is acted on by a spring and may be drawn back by a handle—or withdrawn altogether, by fastening back the handle, thus leaving the door unfastened. Draw-back locks should not be used for the entrance doors of soldiers' barracks unless the catch which keeps the bolt from locking can be secured so that it cannot be released, otherwise, if locked by accident, no one can open the door from the outside without the key.

According to the number of bolts locks are either *single bolt,* amongst which are *dead-shot* locks, acted on by a key only ; *two-bolt* locks, the second bolt acted on by a spring and a handle ; or *three-bolt* locks, the third bolt being movable from one side of the door only.

According to which edge of the door it is fastened to as you enter, a lock is said to be *right* or *left handed ;* and a *knob* or a *ring* lock, according to the description of handle.

Stock Locks.—Stock locks, Fig. 241, are enclosed in a wooden casing, generally oak, and are rarely used for any but inferior purposes, outdoor work, stable doors, etc., where an iron casing would not stand the weather so well. They are made of different kinds and qualities, sometimes iron bound, for strength, and in some cases highly ornamented with metal work. They are mostly single-bolt or dead-shot locks, and are screwed to the lock stile and rail of the door, the bolt shooting into either a common or a box staple. When fitted as draw-back locks they are called *spring-stocks.*

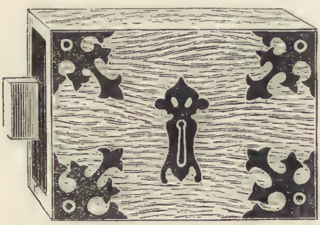


Fig. 241.

Rim Locks.—Iron or copper rim locks, Figs. 242-244—the latter used for magazines, and the former for all ordinary barrack

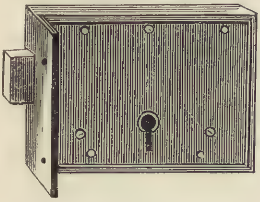


Fig. 242.

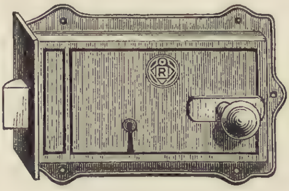


Fig. 243.

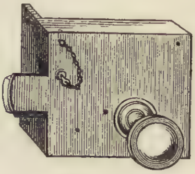


Fig. 244.

purposes—are so called from the metal used in their casing, and the rim which fits round and is secured to the edge of the door. They are fixed on one side of the door, like stock locks, and the bolt or bolts shoot into a box staple.[1]

The holes for the pipe of the key, and for the handle of the door to work in, if bound with brass, are said to be *brass-bushed.*

Mortise Locks.—Mortise locks, Figs. 245-247, are so named

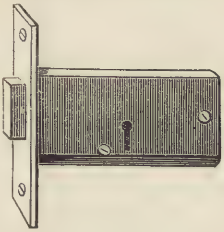


Fig. 245.

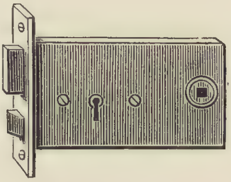


Fig. 246.

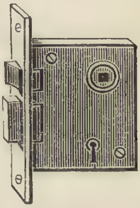


Fig. 247.

from their being concealed from view in a mortise hole sunk, in the case of doors, into the lock stile and rail, so that they are only visible on the edge of the door; the lock rail of a door to be fitted with a mortise lock being, for that reason, made deeper than the other rails. The door must, of course, be of a sufficient thickness to admit of a large enough mortise being sunk in it, otherwise either a rim lock or a stock lock would have to be used. The bolts shoot into a *striking plate* screwed into the rebate of the frame or jamb linings.

There are many ingenious mortise lever locks in use, made to suit all ordinary purposes, which can be fixed in a few minutes

[1] In Hills' new patent rim lock, the lock and frame are separate, allowing of its being used for four hands, *i.e.*, either right or left handed for both doors opening inwards and outwards.

by the aid of a bit, and which do not weaken the door like the large mortise hole required for ordinary mortise locks.

Cabinet Locks.—In addition to the above there are a number of smaller locks, Figs. 248-252, called *cabinet locks,* such as *cup-*

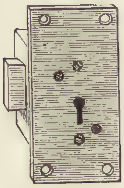


Fig. 248.

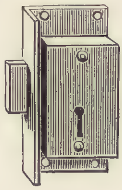


Fig. 249.

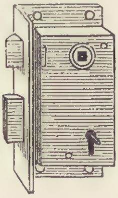


Fig. 250.

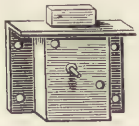


Fig. 251.

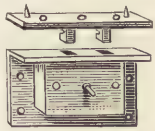


Fig. 252.

board, desk, drawer, box locks, etc., which are termed *straight* when the front plate is screwed flat against the woodwork without any letting in, and *cut* when let in so that the back plate is flush with the surface of the wood.

Locks are also distinguished by their internal mechanism, as *plain* locks, *ward* locks, and *lever* or *tumbler* locks.

Plain Locks.—Plain locks can be opened by any key of the right size, there being no internal arrangement whatever to prevent the turning of the key.

Ward Locks.—In a ward lock projecting pieces of metal called *wards* are fixed in the interior of the lock, which prevent any key from acting on the bolt, unless it is shaped in such a way as to work clear of the wards.

The wards are either small detached pieces or thin slips of iron or copper, bent round to the arc of a circle, in which case they are called round wards; whilst if of brass and cast in one piece, to the shape required, the lock is said to have *solid* wards. According to the number of concentric wards the lock is said to be *one-ward, two-ward,* etc., and according to the shape of the wards they are sometimes called *L, T,* or *Z ward* locks; whilst if the wards are quite plain they are called *one-wheel, two-wheel* locks, etc.

In such locks the wards are attached either to the back lock plate only, or to both the back and front plates, or to a *bridge* fixed midway between the two plates, with or without wards on the front and back plates; and often, for further security, the keyhole is shaped so as to prevent the insertion of any key not correspondingly formed.

All ward locks are more or less easily picked.

Lever Locks.—Lever or tumbler locks rely for their security on one or more *levers, tumblers,* or *latches,* being raised so as to allow of the free motion of the bolt. In the earlier form of lever locks a catch fell into a notch in the top of the bolt, when shot out or withdrawn, and this catch had to be raised by the key, clear of the notch, before the key could move the bolt; but in modern lever locks the levers are thin plates, with a slot in them, which slot must in each plate be raised to precisely the same height, in order to allow of a projection on the bolt sliding through them, both in locking and unlocking. As the slots are cut to fit the projection on the bolt, a most accurately fitting key is a *sine quâ non.* By altering the order of the levers many changes may be rung on the same lock, and a corresponding change of key is of course required for each.

Bows to Keys.—The keys used in War Department Buildings should either have solid bows with W.D. engraved on one side, and the distinguishing name, letter or number of the building, house, and room, on the other; or, if they are ring keys, the open bow should be filled in with brass and engraved, or have a brass label and chain, stamped as required, attached to it; and this applies equally to a flat bow key, if the flat part of the bow is not wide enough to engrave on.

Handles to Doors.—The furniture, such as handles for locks, should be strong and well secured. Stout ring handles, where likely to be exposed to rough wear, are more lasting than knob handles. Amongst the strongest and cheapest knob handles, and the least liable to get loose, are Hill's Imperial Lock Furniture, in which the handle screws on to the spindle, and is prevented from unscrewing by a small screw running through the neck of the handle into a slot in the spindle, the head of this screw being covered by a collar attached to a rose fastened to the door; and, being further secured by being covered by the ornamental rose which screws over the collar of the rose below, it cannot possibly get loose.

Brass knobs should be either cast or filled in solid, otherwise they will soon get indented.

Bolts.

The bolts most generally used are *flat spring bolts,* which are a very common description; *bright rod bolts,* with either *kneed* or

solid ends; best barrel bolts; brass barrel bolts; brass flush bolts, which are let in so as not to project from the surface of the wood; and *Espagnolette bolts* for casement windows (see Fig. 253).

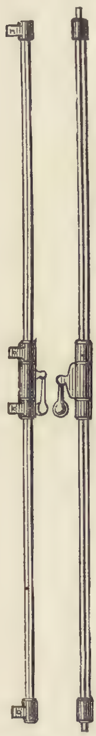


Fig. 253.—Espagnolette Bolt.

Latches.

The *Norfolk thumb latch*, either large, middling, or small, is in ordinary use for barrack purposes, besides which there are *flush latches* for stables; French and Hobb's *latches* for opening with keys; *spring latches* with brass knob handles; *brass spring pulpit latches* and *brass press* or *shutter latches*, specimens of which should be seen to be remembered.

Nails.

Nails are sold by the lb. weight, and are mostly of wrought-iron, either hand or machine made. There is a special *War Office Pattern Book* in every Royal Engineer's Office to guide demands for nails and screws, in which full size drawings of the different sorts in ordinary use are given, together with the weight of the nails—spikes excepted—per thousand of 50 scores, 25 going to the score, and therefore 1250 to the thousand. See also the *War Office Priced Vocabulary of Stores.*

The chief descriptions of nails used are—

Spikes, from 5 to 14 inches long, used for securing heavy timbers together.

Rose nails, both wrought and stamped or machine made, running from $\frac{7}{8}$ to $5\frac{1}{4}$ inches long, taking their name from a fancied resemblance in their heads to the petals of a rose.

Clasp nails, both wrought and cut or machine made, from 1 to 4 inches long; the wrought clasps are of two descriptions—namely, *fine* and *strong*.

Brads, both wrought and cut, from $\frac{1}{2}$ to $3\frac{1}{4}$ inches long, those from $2\frac{1}{4}$ to $3\frac{1}{4}$ inches being called *flooring brads.*

Sprigs, Glazier's sprigs from $\frac{1}{2}$ to $\frac{3}{4}$ inch long, somewhat similar to brads, are used to secure large sheets of glass in their places.

Clouts are made both fine and strong, running from $\frac{3}{4}$ to $3\frac{3}{4}$

inches long, and have either flat or countersunk heads, the latter being used in nailing ironwork to wood.

Tacks are a small description of clouts, closely resembling them; ordinary tacks, from $\frac{1}{4}$ to $\frac{3}{4}$ inch long, are either black or tinned; the larger kinds, running up $1\frac{1}{8}$ inch long, are called *clout tacks.* Some of the smaller tacks are cut or machine made.

There are other special kinds of nails, such as cast and wrought-iron lath nails, for plasterer's work; as also composition and copper nails, for copper sheeting, slating, boat-building, etc.; *copper* brads, tacks, rose nails, etc.; also wire or French nails and steel nails.

Screws.

Screws, from about $\frac{1}{4}$ to 5 inches long, can be obtained of iron, brass, gun metal, or copper, with either flat heads countersunk or rounded heads. They are bought by the dozen or demanded from store by the gross or half gross, and are described by the length as either *fine, middling,* or *strong.* See *War Office Pattern Book* of Nails and Screws; also the *War Office Priced Vocabulary of Stores,* section 4; and Merchants and Manufacturer's Trade Circulars, of which Nettlefold's is one of the most important.

Screws or nails for fixing bolts, locks, hinges, etc., need not be obtained separately, as it is a trade custom to supply them with the furniture itself.

Coach screws are stout screws used for connecting woodwork where strength is required; they are made with flat, projecting heads, generally either square or hexagonal, for screwing in with a spanner.

CHAPTER IV.

SMITH'S AND IRONFOUNDER'S WORK.

THE Smith and Ironfounder, though usually classed together as one trade by builders, will be treated separately.

SMITH.

Under the head of "Smith's Work," in the War Department Schedules, will be found the work of the *blacksmith*, the *coppersmith*, and the *bell-hanger*.

BLACKSMITH.

The blacksmith's work, in connection with the building trades, consists of preparing all the forged ironwork required for ordinary building purposes, such as *pile shoes, dog-irons, straps, bolts, chimney bars, railings, iron roofs*, etc.

Tools.

The principal tools used by the blacksmith, in addition to his forge and bellows, are as follows :—

Anvil, for hammering and shaping his work on.

Standing vice and *hand vice*, for holding work, as in making screws, filing, etc.

Hammers, such as the *hand hammer ; sledge* or *uphand hammers ; back hammer*, between the hand and sledge hammers; *riveting hammer ;* and *setting hammer*, with a broad flat face, also called a *square set* or *flatter*.

Top and *bottom swages* or shaping tools, such as *flatters, rounders, collar tools*, etc., for forging flat and round surfaces, collars on bars, etc. ; the bottom swage fits into a hole in the anvil, and the top swage is held by tongs on the iron and struck by the hammerman.

Files, such as *bastard files,* both *flat, half-round, round,* and *square; smoothing files* of different shapes and sizes, for finishing off; and *warding files* for very fine work, such as filing wards to locks, etc.

Chisels, both *cold, hot, rod,* and *hand chisels.*

Punches, both *cold* and *hot,* as well as a *centre punch,* with a fine point for marking off work.

Tongs of different kinds, such as *hammer, close, hollow bit, forebit, plyer, bolt, duck bills* for rivets, and *scratchers.*

Brace with square and round *rimers* and countersunk *rose bits.*

Screw-plate with set of *taps* for small screws, bolts, and nuts.

Whitworth's *taps* and *dies*—sets of different sizes complete in boxes, with wrenches—for cutting male and female threads on a larger scale than the *screw-plate* is used for.

Stock shears and small *hand* or *scotch shears,* for cutting sheet metal.

Also *bow saw, bow drill, machine drill,* if there is much work doing, *pinchers, spanners, screw-drivers, oil stone, leather holdall* and *breast-plate,* 2 *foot-rule, compasses,* and *callipers.*

Materials.

The principal materials used by the blacksmith are, *coal, iron, steel,* etc., as follows:—

Coal.—The best smith's coal comes from Wales, the small stuff, or screenings, being supplied for that purpose; it is of a hard anthracitic character, but gives out great heat. A sulphurous coal should be avoided as liable to injure the quality of the iron.

Iron.—The iron used for blacksmith's work is either round or flat bar, mostly of the quality known as "merchant bar," which has only been once rolled out; and for better work, when strength is required, an iron equal to what is known as Staffordshire "Best," which is "merchant bar" cut up, fagoted, heated, and again passed through the rolls.

Steel.—*Blister steel* formed by cementation, or heating up in closed retorts with powdered charcoal, and so named from the blistered appearance of its surface, is used for all common purposes, such as steeling picks, facing hammers, etc., where extreme hardness or fineness of texture is not required. *Shear steel* is blister steel cut up, fagoted, heated, and welded under the hammer, until a homogeneous metal of the required quality is

obtained; double shear steel has twice undergone this process. *Cast-steel* is obtained by fusing blister steel, casting it into ingots, and hammering it.

Sand.—Sand is used in welding iron and steel, as a flux for liquefying the oxides which form in the shape of a scale on the surfaces to be united, preventing the perfect contact necessary to form a true weld; whereas, when liquid, they readily squeeze out under the hammer, leaving the surfaces free to unite. The sand for the forge should be quite clean and free from clay and loam.

Borax.—Borax is used as a flux in welding cast steel, its action being quicker than that of sand.

Solder.—A solder for iron and steel is given in Plumber's work, page 258.

Iron Cement.—Iron cement, or *rust joint cement*, if required to be quick setting, is made up of 1 powdered sal-ammoniac (by weight), 2 flower of sulphur, and 80 iron borings, brought to a paste with water; if required to be slow setting, mix up 9 sal-ammoniac, 1 flower of sulphur, and 200 iron borings, which makes a better joint than the first.

Red and White-Lead.—Equal proportions of red and white-lead, mixed with linseed oil, makes a good cement for joints in ironwork.

Execution of Smith's Work.

Besides the forging or hammering of iron to the required shape and size, the smith has constantly to join pieces of iron together by *welding*, or heating it up to a viscid condition, and hammering the surfaces together, when, if at welding or white heat, they will readily adhere to each other.

Welding.—Welding is performed either by laying one piece of iron on another, or by adding it on to the side or end, as in lengthening bars. In the latter case a *scarf weld* (Fig. 254) is used for small work; a *double scarf* (Fig. 255) in steeling the

Fig. 254.

Fig. 255.

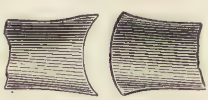


Fig. 256.

point of a pick, as well as for large work, such as a shaft; and a *dab weld* (Fig. 256) in putting together the parts of large forgings.

The first operation in forming all these welds is to *upset*, or

thicken up, the ends to be welded, in order that the dimensions may not be reduced by hammering. The ends to be united are then brought to the required form, heated up to a white-heat, rubbed in the flux, placed in contact when at precisely the right heat, and hammered up. The joint should be well hammered, as the reheating to a white-heat injures the fibrous nature of the iron, which can only be restored by good hammering; hence it is better to dispense with forging, if possible, in all cases where the iron is to be exposed to heavy strains, as all the parts reheated to a white-heat lose more or less their fibrous character, and though this may be restored immediately around the weld, the other parts—which are brought to nearly a welding heat without being rehammered, at any rate sufficiently—are materially injured; and this, no doubt, has led to the idea that the weld is the strongest part of a bar, which is very frequently true, owing to the other parts of the bar having been weakened by reheating.

The steeling, or welding on steel points and faces to the striking and cutting ends of picks, hammers, etc., forms a great part of the work of smiths with R. E. Companies.

Case Hardening.—It is often required to steel or *case harden* the outer skin of soft iron; this is done by heating the iron up to a blood-red heat, in an iron box, with substances rich in carbon and other matters, such as bones, hoofs, bone dust, or leather clippings, and then plunging the iron in cold water. Or the iron, having been first polished, may be rubbed over with prussiate of potash, when at a bright red-heat, and dipped into water when at a dull red-heat.

Malleable Cast-Iron.—Cast-iron articles may be rendered to a certain extent malleable by extracting carbon from them, which is done by heating them up as in case hardening, only surrounded with powdered red hæmatite ore.

Preserving Wrought-Iron.—As iron rapidly oxidises when exposed to the atmosphere, it is often necessary to protect the surfaces from rust before the work leaves the shop, for when once the metal begins to oxidise the process is most difficult to arrest, and, if not entirely stopped before painting, it will soon betray its activity by the peeling off of the paint or any other protecting coat made use of. The metal, fresh from the forge or mill, before it has got much below 600° or the temperature of molten lead, —after the scales of oxide which form on the heated surfaces

have been removed, which readily drop off under the hammer, or by scraping,—is dipped into cold tar, called *japanning*, or into raw linseed oil; or, if too large for dipping, is, while still hot, painted over with one or two coats of tar, oil, red-lead, or one of the oxide of iron paints, such as Wolston's Torbay paint, which are said to be more suitable for ironwork than lead paints.

In the case of iron which has been allowed to cool, and been left exposed to the atmosphere, all signs of rust must be carefully removed by scraping and brushing with a hard brush before applying any protecting coat, whilst in very important work the metal may be chemically cleaned by immersion in a *pickle* of water containing from one to two per cent of sulphuric acid, as in galvanising or coating iron with zinc. The iron should be left in the pickle for three or four hours, and then taken out and well washed in fresh water, when, if the oxide is not completely removed, the surface should be well scoured with sand and the operation repeated. After cleaning, boiling linseed oil, paint, or any other protecting coat should be applied at once, though the metal may be preserved intact for a time by immersion in water rendered alkaline with potash, caustic lime, or soda.

The composition found to be most effectual for preserving the iron of the Britannia Tubular Bridge consists of $\frac{1}{2}$ lb. of sulphate of lime per gallon of coal-tar, with sufficient naphtha to make the mixture work freely. It is largely used for bridge work, the iron having been coated by the manufacturer with boiling linseed oil.

Planed edges and bright surfaces are thoroughly protected from the atmosphere, for purposes of storage and transport, by covering them over with a mixture of rosin dissolved in a little gallipoli oil and turps, or of 1 tallow to 4 white-lead, about an equal bulk of some non-drying oil, such as lard oil, being added, when only a very temporary protection is required, in order to allow of its being readily cleaned off.

Smith's Ashes.—The scales and ashes from the forge should be put on one side for the bricklayer's use, in place of sand, etc., in making *blue pointing mortar.*

Specification for Wrought-Iron.—It is usual to specify for smith's work "all welds, turns, or sets, to be sound; screwed work to have full threads, both external and internal; holes to be punched clean, and burrs cleaned off; all countersinks to be concentric, whether punched or drilled;" but the following clause is quite sufficient to govern the proper execution of the ordinary

wrought-iron work connected with house building, any special work being dealt with separately—"The wrought-iron articles to be manufactured from iron equal in quality to *best* Staffordshire, and to be approved before fixing. They are to be forged clean from the anvil, and neatly, soundly, and perfectly finished."

The qualities of wrought-iron suitable for special purposes being dealt with in the S.M.E. "Notes on Materials," need not be entered upon here.

How paid for.—Smith's work is mostly paid for by the lb. or cwt. Welds and other special pieces of work being frequently paid for at so much each.

COPPERSMITH.

The cost of copper prevents its being used except for such purposes as boilers, lightening conductors, and magazine works, and in castings mixed with tin, zinc, etc., for engine bearings, pivot boxes to gates, etc.

The solders and fluxes for brazing copper are given in Plumber's work, page 258.

For the Board of Trade *Standard Wire and Sheet Metal Gauge*, see Appendix VIII.

BELL-HANGER.

The following remarks are taken from *Building* (Virtue and Co.'s Series).

"**Bell-Hanging.**—The *bell-hanger* provides and hangs the bells required for communicating between the different parts of a building, and connects them with their *pulls*, or handles, by means of cranks and wires.

"The action of the pull upon the bell should be as direct, and effected with as few cranks as possible; and the cranks and wires should be concealed from view, both to protect them from injury, and on account of their unsightly appearance.

"In all superior work, the wires are conducted along concealed tubes, fixed to the walls before the plasterer's work is commenced. The simplest way of arranging the wires is to carry them up in separate tubes to the roof, where they may all be conducted to one point, and brought down a chase in the walls to the part of the basement where the bells are hung. By this means very few

cranks are required, and a broken wire can be replaced at any time without trouble.

"Bell-hanger's work is paid for by the number of bells hung; the price being determined by the manner in which the work is executed. The *furniture* to the pulls is charged in addition, at per piece."

With reference to the above, it should be remarked that concealing tubes behind plaster ought to be avoided as much as possible, as in case of repairs it necessitates cutting about the walls. The tubes for protecting copper bell wires should be of zinc. The ordinary alloy for house bells is 4 copper to 1 tin.

Electric and Pneumatic bells.—Electric and pneumatic bells are much less liable to get out of order than bells hung by wires and cranks; the former, however, require occasional attention to keep the battery in working order, and therefore are most suitable for large establishments such as public buildings, hotels, etc. Care should be taken to get the simplest system of bells and indicators, and the most durable batteries.

Pneumatic bells of the best kind, when once fixed, require no looking after. India-rubber tubing should be avoided, as less satisfactory in its action, more perishable, and more liable to injury than metal tubing.

The pneumatic tubes can be fitted with either pneumatic or electric bells.

IRONFOUNDER.

The ironfounder's trade includes providing, and in some cases fixing, all the cast-iron work required for ordinary building purposes, as in *columns, girders, railings, gratings, pipes, guttering,* as well as in *barrack, stable,* and other fittings, etc.

For patterns of cast-iron articles, manufacturers pattern books should be consulted, such as those issued by Walter Macfarlane and Co., Glasgow.

Ironfounding, in England at any rate, is never done by workmen in employ of a building contractor, or in R. E. workshops, hence a description of the tools used and operations involved need not be entered into here.

Rain-water Pipes and Guttering.—The market forms of cast-iron rain-water down-pipes and eaves gutters are mostly in 6-feet lengths. Down-pipes are either round or rectangular, and eaves gutters generally either half round or ogee section.

Round rain-water pipes vary by $\frac{1}{2}$ inches from 2-inch bore at about 8d., up to 6 inches at about 3s., per yard run. Lengths under 6 feet are about 1d. per yard extra for 2 to 4 inch, and 2d. extra from $4\frac{1}{2}$ to 6 inch pipes.

Rectangular rain-water pipes of simple market patterns are 2 by 2 inches, 3 by $2\frac{1}{2}$ inches, 3 by 3 inches, 4 by 3 inches, 4 by 4 inches; the first about 1s. 6d., and the last about 2s. 10d., per yard run. Heads, shoes, bends, elbows, single and double branch pieces, with from 3 to 30 inch *projections*, are sold at so much each, according to the pattern and bore.

Eaves gutters.—The market sizes of half round gutters run from 3 inches at about 5d., increasing by $\frac{1}{2}$ inches, to 6 inches at about $10\frac{1}{2}$d., per yard run.

Angles and nozzles to ditto at from 6d. to 1s. each. Ogee gutters run from $3\frac{1}{2}$ inches at about $7\frac{1}{2}$d., to 6 inches at 1s. 3d., per yard run; angles and nozzles to ditto, $8\frac{1}{2}$d. to about 1s. 4d. each.

To prevent the leakage of down-pipes causing damp walls, they should always be blocked off from the wall about 1 inch.

Preserving Cast-Iron.—Cast-iron is greatly protected from the atmosphere by leaving intact the hard skin formed by the chilling of the surface of the metal and the fusing of the mould sand, which coats the iron with a silicate glaze and fills up the pores. It may be treated by one of the methods already described for coating wrought-iron, or if a lead-coloured paint is preferred, a common mixture is an equal bulk of white-lead and raw linseed oil, with about half the amount of turps and sufficient lamp-black to produce the required tone.

For cast-iron pipes the process known as Dr. Angus Smith's is the best, which consists of dipping them in coal-tar pitch, distilled to the consistency of wax, and entirely freed from naphtha, and mixed with from 5 to 6 per cent of raw linseed oil, the composition being kept up to a temperature of not under 300° Fahr., and fresh pitch being added as required to keep it from getting too thick. The pipes should not be taken out until they have attained a temperature of at least 300° Fahr.; but the most effectual method is, when perfectly clean both inside and out, to heat them in a suitable furnace up to about 700° Fahr., or just below a red-heat, and then gently lower them vertically into the mixture, withdrawing them after about ten minutes, and leaving them to cool in a vertical position. It is essentially necessary

that all castings so treated (the process is applicable to all castings of a reasonable size) should be quite clean and free from rust, therefore, they should be dipped as soon as possible after leaving the sand; but, if this cannot be done, a coat of linseed oil will protect them for some little time until they can be dipped. The coating when properly done is hard, tough, and smooth, and adheres firmly to the iron. The pitch, ready prepared for use, is sold in barrels.

Specification for Cast-Iron.—For all ordinary purposes it is sufficient to specify that the castings "are to be perfectly sound and clean, and to be cast from good soft gray pig-iron from the second melting, and not run direct from the blast furnace." For very common purposes, where soundness of casting is not of much importance, the iron might be from the first melting—*i.e.* run direct from the blast furnace into the moulds.

The description of cast-iron required for special purposes, and the best tests to apply, where the dimensions have been calculated to resist given stresses, as in girder work, etc., being dealt with in the lectures on "Materials," need not be entered upon here.

Patterns and Models.—For all articles in common use, for pipes and plain plates of all kinds, the contractor is supposed to provide his own patterns without extra charge; as also in all special articles supplied under the War Department Schedules, whenever the number of articles amounts to ten or more.

How paid for.—Ironfounder's work is mostly paid for by the cwt. or by the lb. for small work; by the foot or yard run, according to the weight, for such articles as pipes and eaves gutters; or by the number for articles such as traps, etc.

CHAPTER V.

SLATER'S WORK.

THE Slater's trade in the War Department Schedules comprises all the work connected with the laying and bedding of slates on roofs, besides slate chimney-pots, skirtings, and all slate fittings to urinals, washing-benches, cisterns, etc.

Tools.

The special tools used by the slater are as follows:—

Zax or cutter, with a 6-inch blade, about 2 inches wide, for trimming the slates square, and at the back a sharp-pointed spike about 5 inches long, for *holing* or making the nail holes in roofing slates.

Dog or iron straight edge, with two sharp feet for driving into a block of wood, on which the edges of the slates are laid to be cut by the zax.

Hammer, having the other end slightly curved and pointed for *holing* slates, with a notch on one side of the point for taking hold of and drawing nails.

Scantle or gauge, for marking the slates in trimming and holing them, with notches for catching against the side of the slate, and a point at the end for marking the slate at the proper distance from the edge (the distances between the notches and the point corresponding to the sizes of ordinary slates, and to the distances from their tails, or lower edges, at which they are holed).

Square, for proving and squaring slates.

Ripper, or thin blade of iron about 2 feet long and 2 inches broad, enlarged and rounded at the head, with a notch on each side of the head for drawing nails. It is used in taking off damaged slates, the nails being got at by slipping it up under the slates.

Shaving tool, which is a piece of iron sharpened on one edge,

about 11 inches long and 2 inches wide, with a handle at each end, used for smoothing slabs of slate.

Chisels and mallet, similar to those used by stone-masons, for working slabs of slate.

Materials.

Slate.—The best roofing slates come chiefly from the Festiniog and Bangor districts in North Wales, especially the latter, from Kendal in Westmoreland, and the Delobole quarries in Cornwall; good slates are also obtained in Ireland and in Scotland.

The Welsh slates, especially those from Festiniog, split finer and to a more uniform thickness, and are bluer in colour than the others; those from Westmoreland are rougher, thicker, and consequently inferior, and of a dull greenish tint. Scotch slates are mostly of a thick, coarse description, as are also many of the Irish slates.

Slates are either from a light to a blue gray, a green, or of a reddish tinge; their colour, however, having little to do with their quality, except that when of a dark dull blue or blackish colour they generally absorb moisture readily, and consequently decay more rapidly.

A good slate gives out a clear ringing sound when struck, and is not friable at the edges; if immersed in water there should be no perceptible difference in weight and if partly immersed the non-immersed portion should remain dry. Its surfaces should be smooth planes without any winding, and uniform both in colour and texture.

Slate is quarried by blasting, and the blocks got out are split at the quarries and cut into certain recognised sizes, according to what can be got out of each slab, the larger sizes being generally the most valuable. The harder blocks, which will not split readily into thin layers, are sawn into slabs from $\frac{1}{2}$ to 3 inches thick (weighing about 14 lbs. per foot super of 1-inch slab) for billiard tables, cisterns, baths, shelves, etc.; such slabs may be obtained in the market either with a split face, known as self-faced, rough sawn, planed, or polished (rubbed smooth) on one or both sides.

Special articles are also manufactured out of slate, such as various kinds of coverings for hips and ridges of roofs, etc.

Slate dowels are much used for securing masonry blocks in position, on account of the enormous shearing strength of slate.

Slate enamelled in plain colours, or to imitate marbles, etc., is extensively used for ornamental purposes, as in chimney-pieces, etc., as well as for sanitary purposes, as in stands for urinals, etc.

The names and sizes of the different roofing slates are given in the table, page 233.

Countess, 20 by 10 inches, are the most convenient sized slates to use; and, if a larger size is required, either marchionesses, 22 by 11 inches, or duchesses 24 by 12 inches.

Roofing slates are often cut to fancy patterns, but such an expense would not be allowed in War Department buildings.

Mortar and Cements.—Mortar, hair mortar, and cements are used under certain conditions, such as for upright slating over eaves and gables, for bedding and pointing slating to keep out the weather, as well as for filleting in place of lead, etc., as round chimney shafts, along parapets to gables, etc.

The hair mortar is usually made of 1 stone lime to 3 sand, and 1 lb. of dried well beaten hair to 2 cubic feet of mortar. Plain mortar is usually made of 1 stone lime to 2 sand.

Oil putty made of whiting (pounded chalk) and linseed oil, with more or less white-lead, according to the quality of putty required, as well as red-lead mixed with linseed oil, are used for bedding and pointing joints in slab slate work.

Nails.—The nails used by the slater are either of iron, copper, zinc, or a composition of brass, copper, and tin.

The War Department Schedules specify that nails for countess or duchess slates are to be $1\frac{1}{2}$ inch long, and for larger sized slates 2 inches long.

Iron nails for slating are either cast or malleable, the latter only should be used, and then only for inferior work; though for temporary work cast nails would be good enough. When required to last for any length of time iron nails should either be galvanised, painted, or dipped while hot in boiled linseed oil; the last method is that most in vogue. 2-inch malleable iron slating nails run about 120 to the lb., $1\frac{1}{2}$-inch ditto run about 140 to 160 to the lb., and $1\frac{1}{4}$-inch ditto about 280 to the lb.

Zinc nails are only about half the cost of copper nails, and very little dearer than iron nails dipped in oil or painted; but, being very soft, they are very liable to bend, and so make a good deal of waste.

Copper nails are either wrought or cast, but, as they are very soft, and even when cast are nearly three times the price of iron nails dipped in oil, they are very rarely used.

Composition nails are recommended for all good work; those in most general use are cast, $1\frac{1}{2}$ inch long, running about 144 to the lb., are stiffer than either zinc or copper nails, and have a yellow brassy appearance.

Zinc and Copper Clips.—In executing repairs to slating, when the broken slates have been removed, new slates are slipped up in their places, but as these cannot be secured by nails, they have to be kept in position by some other means. Where the slates are laid on battens, this is best done by a man on the inside of the roof passing pieces of copper wire through the nail holes, and twisting them round the battens; but as this cannot be done when the slates are laid on boards, narrow slips of either zinc or copper, turned over at one end, are slipped up under the slates and made to hook on to the head of the next slate below, the new slate is then slipped up into its place and the lower end of the metal clip turned up so as to hook on to its tail.

Underlinings to Slates.—*Tarred and Asphalted roofing felts* of different kinds are used under slates and tiles as non-conductors of heat and sound, and to keep out wet. For places where the smell of tar would be objectionable inodorous felts can be obtained. M'Neils roofing felts, and M'Ilwraith's or Engert and Rolfe's inodorous felts are widely used; whilst those made by the Patent Durable Roofing Felt Co., 172 Stamford Street, Blackfriars, are particularly flexible. The ordinary quality for underlining slates costs about $\frac{3}{4}$d., and if inodorous, about 1d. per foot super.

When slate boarding is covered with felt it is better to nail battens over it, to secure the slates to, as the circulation of air under the slates increases the durability of the felt as well as the non-conducting properties of the roof.

Waterproof papers, made by the Willesden Waterproof Paper and Canvas Co., 34 Cannon Street, London, can be used for underlining slates; they are odourless and good non-conductors. Either the brown, 2 ply, 54 inches wide at 1s., or the 1 ply, 56 inches wide at 6d., or 7d. for extra stout, is used for the purpose. The 4 ply, 54 inches wide, at 2s. 3d. per yard run, or 3s. for extra brown or neutral green, is used for temporary roof coverings in the same way as corrugated iron, zinc, or felt, without requiring any boards.

Execution of Slater's Work.

Terms used.—The *head* of a slate is its upper edge, and the *tail* its bottom edge.

The *back* of a slate is its upper surface, and the *bed* its under surface.

The *margin* of a slate is that part of the back which is not covered by the overlying slate.

The *gauge* is the breadth of the *margin* or exposed back of the slate.

The *bond* is the extent to which the joints in one course are covered by the course above, the bond being true when in all cases a joint occurs below the centre of the covering slate.

The *lap* is the distance which the tails of the slates in one course overlap the heads of the second course below, which should not be less than 2 inches, but is better 3 inches, and with flat pitches in very exposed situations is sometimes made $3\frac{1}{2}$ inches, and even 4 inches.

The slates used for roofing should be all of one size, trimmed perfectly square on the sides and tails, with true edges, and should be holed at a uniform distance from the tails.

Sorting.—If slates of different sizes are to be used, they should be sorted beforehand into sizes, the larger ones for fixing at the eaves, where the greatest amount of water will be passing; and the rest in order, leaving the smallest for the ridge, where the flow of water is least.

Holing.—The holing of slates is done before they are delivered on to the scaffold for fixing, two nail holes being required in each slate, except for temporary or very inferior purposes. It is laid down in most books that slates should be holed as near to the heads as it is practicable to make the holes without breaking the edge, or within 1 or $1\frac{1}{2}$ inch of the head, the object being to place the holes under the lap, where they would be covered by two thicknesses of slate, so that, in case of one of the upper slates being damaged, there would still be one slate covering the nail hole; but the chance of leakage through a nail hole is very small, whereas, when nailed at the head, as in Fig. 260, the wind acts with so much leverage that the slate is very apt to break away from the nails, and, when one slate goes, the wind can easily rip off all the rest above it, right up to the ridge.

Slates therefore should be, unless ordered to the contrary, holed at a distance from the tail a little greater than the *gauge* + the *lap* of the slates, as shown at Fig. 257, so as to allow the nails to just clear the head of the slate below. It will be seen at once that slates when *centre-nailed*, as it is termed, are held much more firmly than when *head-nailed*.

Boards and Battens.—Slates are laid either on *boards* or on

narrow fillets of wood called *battens;* $\frac{3}{4}$-inch boarding is sufficient for duchess or countess slates, provided the bearers carrying the boards are not more than 18 inches apart in the clear, otherwise 1 inch or thicker boarding must be used, according to the distance apart of the bearers and the weight of the slates to be carried. Battens 2 by $\frac{3}{4}$ inches are generally used for countess and smaller sized slates, for bearings not over 12 inches apart, and 3 by 1 inch battens for such slates as duchesses, but increasing in thickness with any increase in the distance apart of the bearers. The battens are laid at a distance from centre to centre equal to the gauge to which the slates are laid.

Roughly speaking, the weight of battens is only about one-fourth that of boarding, they cost about £1 less per square, and allow of damaged slates being replaced with ease by twisting

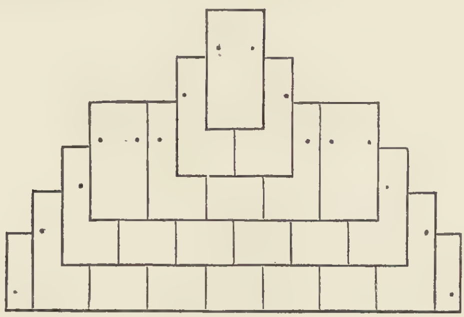


Fig. 257.

copper wire, passed through the nail holes, round the battens from the inside.

Close boarding, which is used for all important buildings, such as barracks, etc., keeps out any leakage better than battens, and forms a covering more impervious to heat and cold.

Tilting Fillets.—Before the slating can be laid, the first point to attend to is that a *tilting fillet,* or its equivalent, is fixed all along the eaves, in order to give a sufficient tilt or *bell-cast* to the slates to insure tight joints at their tails. Small triangular or feather-edged deal fillets are generally fixed for this purpose, nailed just at the edge of the eaves; or the facia board, where used, may be made to project sufficiently above the edge of the slate boarding to do the work of a tilting fillet; $\frac{1}{2}$-inch is a sufficient thickness for any ordinary tilting fillet. When battens are used it is better, in order to dispense with a separate tilting

fillet, to make the lowest batten about $\frac{1}{2}$-inch thicker than the rest.

The skill of the slater is shown in his getting tight joints with as little *bell-cast* as possible, for the more perfectly a slate beds on that below, the less chance it has of cracking under the weight of men going up on the roof for repairs. Again, if there is insufficient *bell-cast*, the wind will drive the rain up under the tails of the slates, lift and rattle them, and often strip them off altogether.

Tilting fillets are also laid against gable walls, party walls, chimney shafts, skylights, and along hips and valleys, in order, by tilting the slates to one side, to throw the water away from such points.

Laying Slates.—In laying the slates the slater, who is supplied with his materials by a labourer, begins at the eaves by laying what is termed the *doubling eaves-course,* which should be a course of slates with an amount cut off from their heads equal to the width of the gauge, and should not be uncut slates laid down on their sides, which is sometimes done to economise slates, though at the expense of the bond.

The tails of the slates forming the doubling eaves-course, as shown in Figs. 258 and 259, rest on the tilting fillet, and

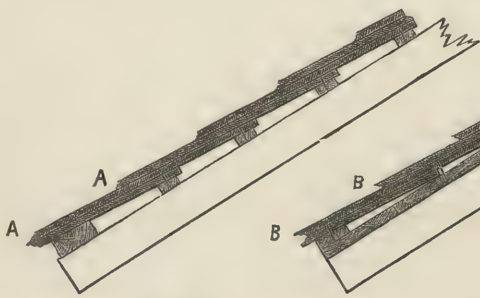


Fig. 258.

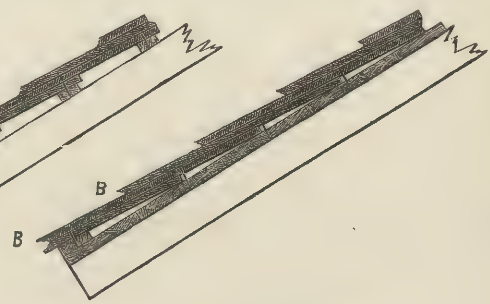


Fig. 259.

project from $1\frac{1}{2}$ to 2 inches beyond the boards or battens, so as to throw water clear into the gutter. The next, or *covering eaves-course,* is now laid, and then the remaining courses up to the ridge course, which has to be cut similar to the doubling eaves-course, or shorter, according to the remaining space to be filled up.

All slates have one side smoother than the other. In the doubling eaves-course the smooth face forms the back, or is laid uppermost; the covering eaves-course is laid, smooth side down, upon the doubling eaves-course, and all the rest of the slates

are laid smooth side down. The reason of this is that the slates are squared and trimmed with their smooth face up, the result being that, though the line along which they are cut is sharp and true on the smooth face, it is jagged and broken along the rough face; consequently by laying them as described, close joints, as at A, Fig. 258, are obtained, whereas, if laid as at B, Fig. 259, the wind would have a better chance of stripping the roof or driving the rain up under the slates.

No slate should be bent or strained in laying, otherwise it will crack if trod on, or even under alterations in the temperature.

Where the slating is not finished to a line at right angles to the eaves, as at hips and valleys, small triangular pieces, only capable of being fixed with a single nail, are constantly occurring, and are a fertile source of leakage, consequently it is better to specify that, whenever such pieces run too small to admit of two nails, special pieces should be cut out of larger-sized slates.

The ordinary sized slates, such as countess and duchess slates, should not be laid on roofs having a pitch under one-fourth the span or $26\frac{1}{2}°$; larger sizes may be used on pitches as low as one-fifth the span or $22\frac{1}{4}°$, whilst the smaller slates require a pitch of at least one-third or $33\frac{1}{2}°$ the span; though much depends upon the site and the amount of lap given to them.

With good work all the slates should be of one size, and the joints in alternate courses should run in a straight line from eaves to ridge, or, in technical terms, the "perpends" should be truly kept.

In cattle and other sheds where ventilation is required, and in temporary and other work, for economy, slates are often laid more or less in open order, as in Fig. 260; whilst some hold that slates should be at least $\frac{1}{4}$ inch apart, as the rain runs off faster than if close laid.

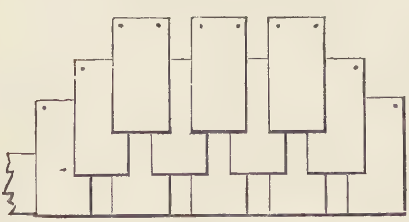


Fig. 260.

Torching, Shouldering, and Rendering.—To keep out draughts, as well as to prevent leakage on exposed sites, from driving rain or melting snow, the slates are often pointed with hair mortar on the inside, or *torched*, as it is termed; or they may be *shouldered* or bedded for about 2 inches at their heads in hair mortar, generally mixed with coal ashes to give a slate colour,

which is more effectual than mere torching, as it does not get loose and drop out, whilst it tends to keep the tails of the slates tight down.

Sometimes the slates are *rendered* on the undersides with hair mortar, both to keep out the weather and maintain a more equable temperature within.

Slate Hips and Ridges.—Patent slate hips and ridges are much used on account of the expense attendant upon the use of

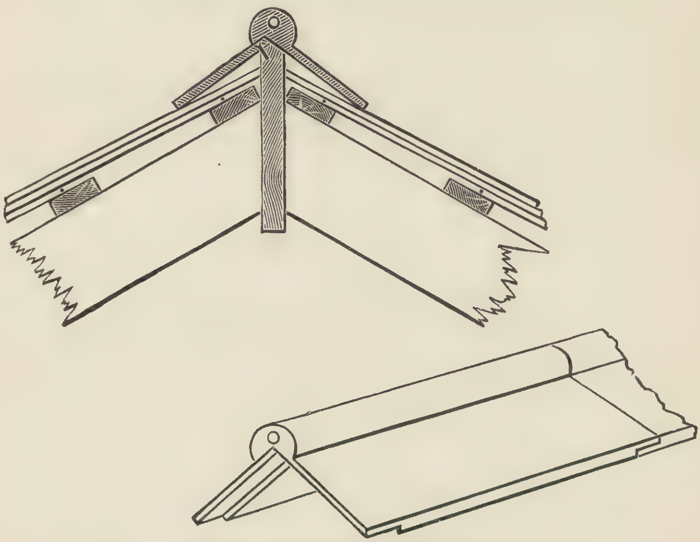


Fig. 261.—Williams' Slate Ridge.

lead. They are made to suit roofs of different pitches, and require careful fixing in accordance with the instructions issued by the different patentees. The chief kinds in use are "Williams'" slate ridging in two pieces, Fig. 261, the roll and one of the wings being in one; and "Thomas'," Figs. 262 and 263; and "Jennings'," in three pieces, Fig. 264. They all cost about 11d. to 1s. 8d. per foot run, according to the size—namely, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, or 3 inch roll, and from 5 to 7 inches width of wing, with 1d. extra if the ends of the wings are rabbeted.

Thomas' system, Fig. 262, called Bangor Patent Slate Ridging, is an improvement on Williams', whilst Jennings' is very simple, but the roll being of galvanised iron is not so durable as slate, whilst it cannot be cut to the required lengths without exposing the iron to certain corrosion, unless regalvanised.

Fig. 264 shows Jennings' ridging, and his method of laying slates with grooved lead cames.

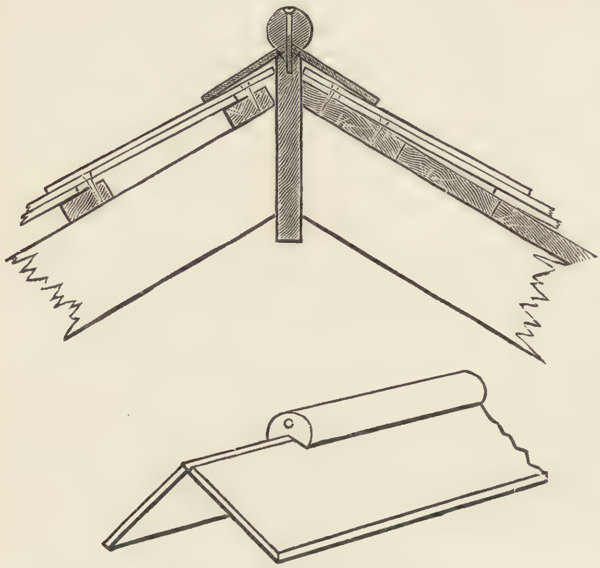


Fig. 262.—Thomas' Slate Ridge.

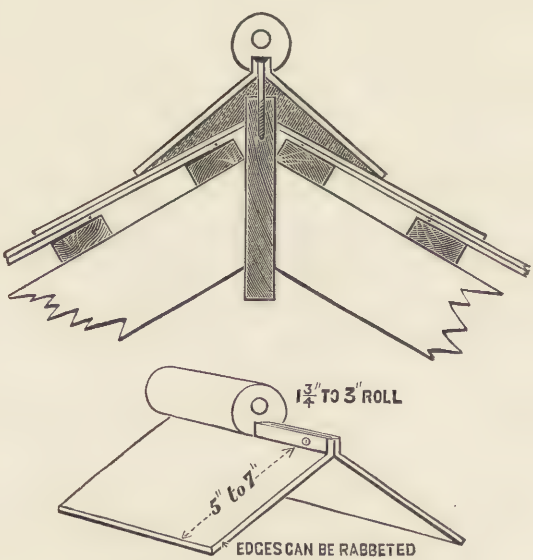


Fig. 263.—Jennings' Slate Ridge.

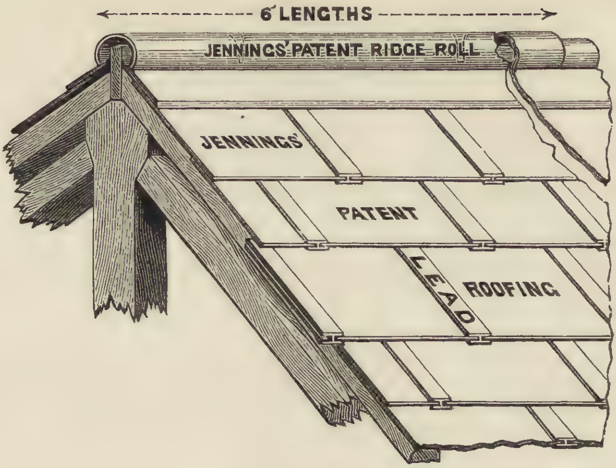


Fig. 264.

Estimating Slater's Work.

The work upon slab slate, or the slate mason's work, is measured and paid for in the same way as stone mason's work.

The slating of roofs is paid for by the square of 100 feet super. In addition to the feet super of slating so measured on a roof, the custom is to allow extra for cutting and waste to *eaves*, to cover cutting the doubling eaves-course, as well as for *raking cuts* to hips and valleys, and in gutters in order to get the required fall. This is generally done, in the case of eaves, by adding the feet super obtained by multiplying the feet run of eaves by the gauge, in feet, to which the slates are laid; and in the case of raking cuts, by taking half the number of feet run of cutting, or the feet run of hips and valleys, as the feet super to be added; which is the same as allowing the feet run of raking cut by a breadth of 6 inches; a similar allowance of 6 inches in breadth is also usually made for measuring round deductions over 5 feet super, at chimney shafts, skylights, etc. For circular work—*i.e.* slating on curved surfaces—allow one-third more than the actual area.

Such work as hair mortar and cement filleting is paid for by the foot run.

Ordinary roofing slates are sold by the number, generally by the thousand of 1200, and are therefore called *count slates*, or if required in smaller numbers by the 100. Some of the largest sized slates are however sold by the ton, and hence are called *ton slates* or *weight slates;* or by the foot super for small quantities.

In estimating the number of slates required per square of 100 feet super, the width in inches of the gauge to which the slates are to be laid must be ascertained, which, multiplied by the breadth of the slate to be used, also in inches, gives the margin or exposed surface of a single slate, and this divided into 14,400, or the number of superficial inches in a square, will give the number of slates to a square.

If $L =$ length of slate, and $l =$ lap, then the gauge will $= \frac{L - l}{2}$. Thus the gauge of countess slates (20 by 10 inches), laid to a 3-inch lap, will $= \frac{20-3}{2} = 8\frac{1}{2}$ inches, and the number of countess slates required per square will be $\frac{14400}{8\frac{1}{2} \times 10} = 169{\cdot}44 = 170$ (see column 7 of table, p. 233).

The number of feet super which a M (1200) countess slates, laid to a 3-inch lap, will cover (the margin of each slate being $8\frac{1}{2} \times 10 = 85$ inches) will be $= \frac{1200 \times 85}{144} = 708$ feet super (see column 6 of table, p. 233).

The War Department contract for slates specifies "1000 slates to be understood to mean ten hundreds of 100 each, and not 120 per hundred; no broken or damaged slates are accepted, but the following additions to the quoted prices are made for risk of breakage or damage—3 per cent in England, 4 per cent in Scotland, $2\frac{1}{2}$ per cent in Wales, and 5 per cent in Ireland and the Channel Islands."

In addition to the estimated number of slates required for a roof, based on the following table, an allowance must be made for the *doubling eaves-course,* which exposes no margin; the number of slates to be added is arrived at by taking the feet run of the eaves and dividing it by the breadth of the slates in feet.

For the same reason the actual number of feet which a given number of slates will cover (arrived at from column six of table) must be reduced, on account of the doubling eaves-course, by the feet super got by multiplying the feet run of eaves by the gauge of the slating, in feet.

The division of the slates into first and second quality depends on their smoothness, regular shape, thickness, and colour; second quality slates generally run to a thicker gauge, and therefore weigh heavier than the first quality.

The following table of the different slates in use has been enlarged from one in the *Timber Importer's, Timber Merchant's, and Builder's Standard Guide.* The weights must be only regarded as approximate, for instance: Welsh slates run a few lbs. lighter, and Westmorelands a few lbs. heavier :—

Description.	Size in Inches.	Weight. 1st quality, per thousand of 1200.	Weight. 2d quality, per thousand of 1200.	Cost. 1st quality, per thousand of 1200.	Cost. 2d quality, per thousand of 1200.	Covered sq. ft. by M. of 1200. Laid to 3″ lap.	Slates required for square. Laid to 3″ lap.	Nails, at 2 to each slate, required per square. Laid to 3″ lap.	Square feet covered, per ton.
	1	2	3	4	5	6	7	8	9
Ton slates, sold by weight.		*Cwt.*		£ *s.* *d.*	£ *s.* *d.*				
Queens . .	36 × 24	...	...	3 6 10	...	3300	37	74	300
Rags . .	36 × 24	...	...	2 8 6	...	3300	37	74	234
Imperials .	30 × 24	...	...	...	...	2700	45	90	
Tally slates, sold by count.									
Empress .	26 × 16	95	...	15 12 0	...	1533	79	158	
,, small	26 × 14	90	...	14 5 9	...	1341	91	182	
Princess .	24 × 14	70	90	12 15 0	11 10 9	1225	99	198	
Duchess .	24 × 12	60	80	11 0 5	9 14 5	1050	115	230	
Marchioness .	22 × 12	55	70	9 4 8	8 1 6	950	127	254	
,, small	22 × 11	47½	60	8 8 5	7 3 6	870	138	276	
Countess, wide	20 × 12	50	...	8 8 9	...	850	142	284	
Countess .	20 × 10	40	54	7 8 10	6 4 5	708	170	340	
Viscountess .	18 × 10	36	47	5 14 9	4 13 7	625	192	384	
,, small	18 × 9	31	40	4 13 2	4 2 0	562	214	428	
Ladies . .	16 × 10	31	42	4 7 6	4 2 7	541	222	444	
,, large .	16 × 8	25	33	3 9 3	2 18 6	433	278	556	
,, small .	14 × 12	33	44	3 15 8	3 5 7	550	219	466	
,, ,, .	14 × 8	22	26	2 10 1	2 7 7	366	328	656	
,, ,, .	14 × 7	20	22	1 18 6	1 17 10	320	375	750	
Doubles .	13 × 10	25	31	2 14 11	2 9 2	416	289	578	
,, . .	13 × 7	18	21	1 14 8	1 14 2	291	413	826	
Smalls or singles	12 × 8	18	22	1 13 3	1 11 10	300	400	800	
,, .	12 × 6	14	14	1 1 11	1 0 10	225	534	1068	
,, .	11 × 5½	12	...	1 0 8	...	183	655	1310	

The cost given is "net cost" to importer, which of course varies according to the state of the market, though the prices show the relative value of the different kinds.

Queen's and Rags vary in size, but average 36″ × 24″.

CHAPTER VI.

PLASTERER'S WORK.

THE plasterer uses mortars and cements of different kinds for external walls, to give a better face to the work, as well as in many cases to form a waterproof covering; and, for interior walls and ceilings, to afford a smooth surface which can be papered, painted, distempered, etc., as may be required; also for decorative and other purposes, such as mouldings, cornices, skirtings, etc.

Under ordinary circumstances the first coat is either applied direct on to a wall surface, as on to brickwork, in which case the wall is said to be *rendered;* or it is laid on to lathing, in which case it is spoken of as *lath and plastered*, or *lath and laid.*

Tools.

The principal tools used by the plasterer are as follows:—

Spade and *hod* similar to those used by the bricklayer's labourer, *gauges* or boxes for measuring his materials, and *pails* for water, etc., for use in mixing and carrying the stuff.

Hawk, a small square board, about 10 inches square, with a short handle at the centre of the back, for holding the stuff on when applying it with the trowel.

Feeding spade or *server,* which is a small spade with a long handle, with which the *hawk-boy* beats up the mortar on the board to prevent its setting, and feeds the plasterer's *hawk* with small pats at a time.

Screen, or large upright sieve, as well as a small sieve, for screening the materials, or separating the coarser from the finer particles. The lime and sand may be most efficiently mixed by screening them together.

Drag or *larry,* which is a three-pronged rake for mixing the hair in making hair mortar.

Lathing hammer, for nailing the laths, with a hatchet edge at back—and sometimes a notch on one side for taking out nails—for roughing surfaces to obtain a key for the plaster, as well as for hacking off old plaster. The face is chequered over with indented lines to prevent slipping on the heads of the nails.

Trowels, for laying on plaster, such as the *plastering* or *laying tool*, a thin polished steel plate, about 10 inches long by $2\frac{1}{4}$ inches wide, rounded at the point, square at the heel, and slightly convex on face, with a wooden handle fastened at the back, parallel with the blade; and *gauging tools*, or ordinary trowels from 3 to 7 inches long, for *gauging* the stuff, which implies mixing plaster of Paris with it, for the purpose of getting it to set quicker and harder.

Floats of three kinds—namely, the *Derby float* or long wooden board, with a flat face and two handles, for two men to work, used in three-coat work for floating the second coat to a smooth level surface; the *hand float*, which is a small flat piece of board, with a handle at back like the plastering tool, used for floating and smoothing off finishing coats; the *quirk float* or mitre of wood splayed off to an angle at one corner, used for floating in angles and mitres to mouldings.

Moulds for running mouldings or curved surfaces.

Jointing tools or thin triangular steel plates of different sizes, fitted with a handle at the back, and brought to a very acute angle at the point, for finishing angles and mitres to mouldings.

Jointing rule of wood, about 5 feet long by 3 inches wide, bevelled off to an edge, for floating in angles as in the corners of rooms.

Straight edge or long board shot true on one edge, for traversing walls or ceilings in order to get them perfectly level.

Trammels or rods fitted with sliding points for use as compasses in striking large curves, etc.

Small tools, also called *stopping* and *picking-out tools*, used for modelling ornaments, finishing off mitres, etc.

Brushes for dusting, wetting, and colouring, which are broad and thin, and of coarse and fine hair for rough and fine work.

Materials.

The following are the principal materials used for plastering:—

Sand.—It is essential that no loamy or clayey sand should be

used for plaster, as it renders it rotten and leads to decay in the laths; if the sand is not very clean it should be washed. Sea-sand must also be avoided, as the salt it contains absorbs moisture from the air, which renders the plaster damp; whilst the evaporation of the moisture in dry weather leaves a saline efflorescence on its surface. If no other sand can be got, the salt must be well washed out with fresh water.

Water.—The water used by the plasterer should be clean, and free from salts which absorb moisture from the atmosphere, sea-water being therefore inadmissible.

Limes.—Fat limes are chiefly used for indoor plastering, on account of the readiness with which they slake into a fine powder, whilst they set, or rather harden, sufficiently quickly for ordinary purposes.

If a hard stone or hydraulic lime is used, there are apt to be, even when well ground, small lumps of unslaked lime, which, though no bigger than a pin's head, will destroy the surface of the work by slaking or *blowing* after the finishing coat has been applied. From want of attention to this point new walls and ceilings may sometimes be seen breaking out all over in pustules or blisters, causing both loss of time and extra expense to put them to rights.

Plaster.—Plaster of Paris, which is calcined gypsum or sulphate of lime, is supplied of two qualities—namely, "fine" or "coarse"; the former, which is the dearer, being used for mouldings, castings, etc., and the latter for gauging or mixing with common lime and hair plastering, to promote rapid setting.

Coarse Stuff.—Coarse stuff, or hair mortar, is used in ordinary plastering for the first coat in two-coat work, or the first and second coat in three-coat work, and consists of lime, sand, and hair, usually mixed in the proportion of 1 or $1\frac{1}{2}$ sand to 1 lime, in order to insure stiffness; the sand in all cases being fresh-water sand, the water fresh, and about 1 lb. of hair being mixed with every 3 cubic feet of mortar. If mixed in a mill the hair should only be put in at the last moment, or it will get broken and torn into short pieces. The hair, which comes in bags from tanner's yards, should be long, sound, and strong, free from grease and dirt, and should be well beaten before use, in order to separate the hairs; this is usually done by a man or boy with two laths in each hand. If there is sufficient hair in coarse stuff for ceilings, it should, when taken up on a spade or trowel, hang

down from the edges without dropping off. For walls the hair may be rather less than in top stuff for ceilings.

Fine Stuff.—Fine stuff, used for the setting or finishing coat in ordinary plastering, consists of a pure lime slaked with a small quantity of water, and screened through a fine sieve to remove any hard or unslaked particles, sufficient water being now added to bring it to the consistency of cream; it is then left to settle in a tank or tub, the surface water is drained off, and it is allowed to evaporate until thick enough for use. For top stuff in ceilings a small amount of white hair is often mixed with the fine stuff.

Putty.—Plasterer's, like bricklayer's *putty* (p. 52), is only more carefully prepared fine stuff, and is used for making *gauged* stuff.

Gauged Stuff.—Gauged stuff, or "putty and plaster," is used for rapidly finishing walls, running cornices, mouldings, etc. It is composed of from $\frac{1}{2}$ to $\frac{4}{5}$ fine stuff or putty, according to the rapidity of setting required (say $\frac{1}{2}$ for cornices and $\frac{4}{5}$ for walls), and the rest plaster of Paris. It has to be mixed in small quantities at a time.

When time is an object each successive coat of plaster can be gauged in order to quicken its setting, but too much plaster will cause it to crack from setting too fast.

Plaster of Paris should not be used for outside work, as it is dissolved by rain.

Stucco.—*Common stucco* is made up of 1 hydraulic lime to 3 or 4 clean washed sand. When made with 4 coarse sand and finished in imitation of stone, it is called *rough stucco,* the grit being raised with a hand float faced with felt, in order to give the appearance of the coarse grain of a rubbed sand or grit stone; it is applicable to outside walls, passages, and dados to rooms, etc.

Trowelled stucco is a term applied to a mixture of two-thirds fine stuff and one-third very fine clean sand, and is used for finishing internal surfaces intended to be painted; when hair is mixed with it, it is called *bastard stucco.*

Cements.—In addition to the plasters above mentioned, many cements are used, as well as blue lias and other hydraulic mortars, in order to obtain a hard non-porous surface capable of resisting exposure to the weather or wear and tear; as also for sanitary purposes, in such places as hospital wards, where the absorbent surface of ordinary plaster is liable to harbour disease.

The object aimed at in all cements, for internal work especially, is to get a material which will work kindly under the trowel

without setting too fast, and yet one which will harden and dry rapidly, so as to allow of being painted soon after it has set.

Most of the internal cements may, by constant trowelling and wetting, be worked up to a very hard surface, and will take a polish like marble; they are rubbed down with "grit stones" of different degrees of fineness, a stopping of semi-fluid plaster being rubbed in to fill up all the pores, and then polished up with "snake stone," and finally with putty powder and flannel. The following are the principal cements used by the plasterer:—

Keene's Cement.—Keene's cement is a mixture of plaster of Paris and alum, the "fine" quality is perfectly white and takes a brilliant polish; being chiefly plaster of Paris it is only suitable for internal work; when applied to brickwork, the first or rendering coat should be of Portland cement. The "coarse" quality does not take such a good polish, but forms a hard surface which can be painted or papered within a few days of its application.

Parian Cement.—Parian is a white cement, said to be a mixture of plaster of Paris and borax; its chief merit is that, when applied to newly-built or damp walls, it sets rapidly and can be painted at once, or, as workmen say, "the brush should follow the trowel." It works much freer than either Keene's or Martin's cement, and is therefore preferable for large surfaces which have to be hand floated before trowelling; but the latter are *fatter*, and produce sharper arrises and mouldings. Four bushels of Parian cement, with an equal proportion of clean washed sand, will cover 10 yards super at $\frac{1}{2}$-inch thick. It can be polished in different colours in imitation of marbles, etc.

Martin's Cement.—Martin's is also a white cement for internal purposes, it will cover a greater surface in proportion to its bulk than any other cement in use, and is manufactured of different qualities as "coarse," "fine," and "finest."

One cwt. of Martin's cement, with an equal proportion of sand, will cover 6 or 7 yards super $\frac{1}{2}$-inch thick. For walls or floors a $\frac{1}{2}$-inch coat of 1 coarse cement to $1\frac{1}{2}$ clean washed sand, and an $\frac{1}{8}$-inch finishing coat of pure cement, is sufficient.

Portland Cement.—Portland cement is almost universally used now for external work, as well as for the groundwork of cement dados, skirtings, etc., in internal work.[1] The quicker setting varieties, weighing from 90 lbs. to not much over 100 lbs. per striked imperial bushel, should be used, the great strength

[1] For specification for Portland cement, also Petrifite, *see* Appendix IV.

of the heavier and slower setting cements being no object. It wears best with a hand-floated, gritty surface, and not trowelled.

Roman Cement.—Roman cement is a rich brown colour, weighs about 60 lbs. per cubic foot or 75 lbs. per bushel, and sets in about 15 minutes. Though cheaper, it is not as reliable, and only about half as strong, as Portland cement, and is now little used except for quick setting work.

Medina Cement.—Medina is a superior variety of Roman cement, manufactured from septaria obtained from the Isle of Sheppy. It is of a lighter brown than Roman cement, sets very rapidly, and has been used successfully in tide work for pointing and rendering walls exposed to as much as 15 feet of water.

Mastic.—Mastic is specially applicable to outside work to be painted at once, but being costly it has given way to Portland cement.

Atkinson's Cement.—The same may be said with regard to Atkinson's cement, it is warmer in colour than Portland, and being quicker setting is very useful for castings.

Selenitic Cement.—*Selenitic cement* or *lime* is the invention of the late Major-General H. Y. D. Scott, Royal Engineers; it has the great advantage of combining cheapness with rapid setting and ultimate hardness, though plasterers say that it requires more time and labour to work up to a good face than common plaster, and care has to be taken or fine cracks, called *fire cracks,* are liable to develop themselves on the surface, sometimes owing to the setting coat being applied too soon, and hardening before the plaster behind has ceased to shrink. The key to its manufacture is that the energetic slaking of a feebly-hydraulic lime (tender-burned and containing not less than 20 per cent of clay) is stopped by adding a certain proportion of plaster of Paris to the water which is to be used for mixing with the lime, the result being that the properties of a cement are imparted to it.[1]

Selenitic lime, all ready prepared for use,—that is to say, ground and mixed with the requisite proportion of plaster of Paris, so as to guard against mistakes arising from having to add plaster of Paris during the process of mixing,—is now supplied by agents of the Company in most localities, whose names can be ascertained by reference to the Company's London office.

[1] Selenitic mortar with 6 sand, sets far harder and much quicker than common mortar with 2 to 3 sand. For the method of making it from ordinary hydraulic limes, see Appendix III.

The following instructions for making selenitic cement mortar are issued by the Patent Selenitic Cement Company, 6 Wharf, Belvedere Road, Lambeth, London, from whom any further information can readily be obtained:—

"*If prepared in a Mortar Mill.*—Pour into the pan (a 5-foot pan is referred to) of the edge-runner 4 full-sized (3 gallon) pails of water. Gradually introduce 2 bushels of prepared lime, and grind to a creamy paste, but not thinner. Add 10 or 12 bushels of clean sharp sand, burnt clay, or other suitable ingredients, and grind till thoroughly incorporated, adding more water if necessary.

"*If prepared in a Tub.*—When a mortar mill cannot be used, an ordinary plasterer's tub (holding 30 to 40 gallons), with an outlet or sluice, may be substituted, into which pour the water, then the plaster, and stir well to a creamy paste as above, then run it into the centre of a ring formed with the sand, and turn it over two or three times, well mixing it with the larry or mortar-hook.

"*Plastering on Brickwork.*—The above is suitable for bricklayer's mortar or rendering and floating, which can be done similar to Portland cement, requiring no hair.

"*Plastering on Lathwork.*—Proceed as above, but use only 6 to 8 bushels of clean sharp sand, and add two hods or 4 pails of ordinary well-matured and well-mixed lime putty. In a mill the putty must be added last, as grinding destroys the hair.

"*Setting Coat and Trowelled Stucco.*—Mix as above 4 pails of water, 2 bushels of selenitic lime (first sifted through a 24 × 24 mesh sieve), 6 pails or two hods of ordinary lime putty, and 3 bushels of fine washed sand. This should be well hand-floated, and trowelled as for trowelled stucco; it will also make good pointing mortar for brickwork by adding more sand. If a hard selenitic surface is not necessary, ordinary fine stuff can be used for the setting coat.

"It is of the utmost importance that the order indicated in preparing the mortar, etc., should be strictly observed; first well-mixing the selenitic lime in the water before adding the sand, otherwise the lime will heat and spoil.

"*Selenitic Clay Finish.*—The use of ground selenitic (or Barrow) clay improves the mortar, and renders it more hydraulic. Mix, as described, 5 pails of water, 1 bushel selenitic lime, 3 bushels selenitic clay, 2 bushels fine washed sand, 1 hod chalk lime putty. Well hand-floated and trowelled, this will produce a surface equal to Parian or Keene's cement, and, being non-

absorbent and readily washed, is suitable for hospital walls and public buildings, etc.

"The following remarks should be carefully observed :—

Selenitic lime or mortar must not be used where required to be gauged with plaster, as for cornices, screeds, etc.

Sand or other ingredients must be clean and free from loam.

When the sand is very dry more water will be required.

Only gauge sufficient mortar for use during the day.

If the mortar heats and sets too rapidly, add a small quantity of plaster, but not more than $\frac{1}{2}$ pint per bushel of lime, mixing it with the mortar before the selenitic lime is added.

Burnt clay, ballast, cinders, or stone chippings, can be used, wholly or partly, in place of sand with great advantage.

"Plastering on walls can be finished by the above processes, as two-coat work, in twenty-four hours; while the ceilings can be floated immediately after the application of the first coat, and be set in forty-eight hours."

Laths.—In the case of plaster ceilings fixed to the undersides of wooden floors, plaster coverings to wooden partitions, or plaster carried by battens plugged to the face of a wall, as a safeguard against damp, the first operation of the plasterer is *lathing.*

The ordinary plasterer's laths are thin strips of some straight-grained wood—generally fir in England—split into 3 or 4 feet lengths about 1 inch wide, and called *single laths* if about $\frac{3}{16}$-inch thick, *lath and a half* when about $\frac{1}{4}$-inch thick, and *double laths* when about $\frac{3}{8}$-inch thick.

The wood used for splitting into laths is mostly Baltic fir, which comes chiefly from Memel and other Baltic ports in half round logs called *lathwood*, being merely the young trees cut into lengths and split down the centre. The laths are consequently frequently called "Memel" or "Baltic laths," and are mostly sold in bundles containing 500 feet run, or 125 laths if 4 feet long. They should be free from knots and splits, and all crooked or knotty laths should be sorted out, and not used for good work.

Sawn laths, being of a uniform thickness, require much less plaster and labour to cover and bring them to a true surface than split laths, but they are seldom used, being considered liable to break off short. Iron laths are now made, also wire lathing and expanding iron lathing; but their advantages are doubtful, being more expensive, whilst ordinary lath and plaster is highly fireproof in itself.

The bearers carrying the laths are not generally more than 1 foot apart from centre to centre, or else in the clear—the former being more suitable to the lengths of the laths—in either case laths and a half should be used for ceilings, in order to prevent any sagging and cracking of the plaster; though single laths would be strong enough for vertical walls. If the bearers are at greater intervals apart, stronger laths would become necessary.

Lath Nails.—Lath nails are either *wrought, cut,* or *cast,* the latter being the cheapest and therefore most generally used, except for oak laths, when, if iron nails are used, they should be either wrought or cut. They should be 1, $\frac{7}{8}$, or $\frac{3}{4}$ inch long, according as the laths are *double, one and a half,* or *single.*

If nails are bought at so many lbs. per M., it must be remembered that the ordinary thousand of nails will only run about 750 to 850; therefore it is better to ascertain the average number to the lb., and buy by the lb.

A bundle of 3-feet laths would require 668 nails, and of 4-feet laths 625 nails, if properly nailed on to bearers 1 foot from centre to centre. $\frac{7}{8}$-inch cut lathing nails run about 380 to the lb., and $1\frac{1}{2}$-inch about 114 to the lb.

Execution of Plasterer's Work.

Lathing.—In order to get a perfectly true surface upon which to commence the operation of lathing, the undersides of the joists in ceilings, or the battens or quartering in case of walls, have to be proved with a straight edge, or mould for curved surfaces, and, if necessary, corrected by adzing off projections, or "firring up," which is filling in hollows by nailing on slips of wood of the required thickness. When ceiling joists are used, they should be adjusted to the proper level, to save the labour of firring up.

It is essential to the proper keying of the plaster between and at the back of the laths that they should, especially in ceilings, be in contact with as little wood as possible, therefore narrow fillets or double laths should be nailed all along the centre of timbers or joists over 3 inches broad, and the laths nailed to the fillets; this is called *counter-lathing.*

The laths are laid side by side and about $\frac{3}{8}$ of an inch apart, the ends should abut and not overlap each other, and they should

be secured by one nail at each end and one at each intermediate point of support.

As it would be too troublesome to make each lath break joint with those on either side of it, they are laid *matching* or breaking joint in bays from 3 to 4 feet in width, in order to diminish the risk of cracks, which would extend along and mark the lines of junction if laid in long rows. This is not of so much importance on walls as it is on ceilings.

Mr. E. Dobson in *Building* (Virtue and Co.'s Series) says, "In the Midland Districts of England reeds are much used instead of laths, not only for ceilings and partitions but for floors, which are formed with a thick layer of coarse gauged stuff upon reeds. Floors of this kind are extensively used about Nottingham, and from the security against fire afforded by the absence of wooden floors Nottingham houses are proverbially fireproof."

The hollow spaces behind lath and plaster on battens are objectionable from their forming runs for vermin, as well as channels through which offensive gases, once finding their way behind the plaster, can travel to any part of the building.

Lath Plaster, one coat.—The first coat of coarse stuff on laths is called the *pricking-up* coat, and work finished with one such coat smoothed off with the trowel would be called *lath and lay* or *laid*, or *lath and plaster one coat*, which is the term used in the War Department Schedules. The stuff should be worked on well with the trowel, and though thin enough to key up, or pass readily between the laths, it should be stiff enough not to break away from the keying as it is put up, and moreover should not be thicker than is necessary to form a truly level surface over the laths, from $\frac{1}{4}$ to $\frac{3}{8}$ inch thick, as any unnecessary weight of plaster only renders it more liable to break away from the keying.

Lath, Plaster, Set.—If a thin finishing coat of *fine stuff* or *gauged stuff* is added, it becomes *two-coat work*, and is called *lath, plaster, set*, or *lath, lay, set.* In order to form a key for the setting coat, the surface of the pricking-up coat is swept over with a birch broom while still soft.

Whenever more than one coat of plaster is applied, the last coat should be wetted with a hog's bristle brush dipped into a pail of water before the next is added, which would otherwise shrink away from that previously laid.

Lath, Plaster, Float, and Set.—*Lath plaster* (or *lath lay*) *float and set*, constitutes *three-coat work.* In this case the pricking-

up coat, while still soft, is scratched or *scored* all over with the end of a lath, which should be held at an angle to the face of the work in order, by undercutting the scoring, to form a better key for the floating coat. The scoring should be carefully done in parallel lines about 3 inches apart, and then crossed over with a second set of parallel lines at an angle to the first. A special scoring tool, with several teeth, is sometimes used to expedite the process; whilst plasterers often take several laths in their hand at the same time, and scratch the surface over at random, but this should not be allowed. The setting coat of fine stuff is applied to the floating coat as described for lath, plaster, set.

Floating Coat.—When the *pricking-up* coat is quite firm the second or *floating coat* is, when good work is required, applied as described in the following extract from *Building*, p. 120 (Virtue and Co.'s Series):—

"The operation of floating is performed by surrounding the surface to be floated with narrow strips of plastering, called screeds, brought perfectly upright or level, as the case may be, with the level or plumb-rule; thus, in preparing for floating a ceiling, nails are driven in at the angles and along the sides about 10 feet apart, and carefully adjusted to a horizontal plane, by means of the level. Other nails are then adjusted exactly opposite to the first, at a distance of 7 or 8 inches from them. The space between each pair of nails is filled up with coarse stuff, and levelled with a hand float; this operation forms what are called *dots.* When the dots are sufficiently dry, the spaces between the dots are filled up flush with coarse stuff, and floated perfectly true with a floating rule or long straight edge, called a Derby float. This operation forms a *screed,* and is continued until the ceiling is surrounded by one continuous screed, perfectly level throughout. Other screeds are then formed, to divide the work into bays about 8 feet wide, which are successively filled up flush, and floated level with the screeds.

"The screeds for floating walls are formed in exactly the same manner, except that they are adjusted with the plumb-rule instead of the level. The grounds for joiner's work, such as for skirtings, etc., form screeds for the plasterer to work by, and to start the feet of his wall screeds from.

"After the work has been brought to an even surface with the floating rule, it is gone over with the hand float and a little soft stuff, to make good any deficiencies that may appear.

"The operation of forming screeds and floating work, which is not either vertical or horizontal, as a plaster floor laid with a fall, is analogous to that of taking the face of a stone out of winding with chisel-drafts and straight edges in stone-cutting; the principle being in each case to find three points in the same plane from which to extend operations over the whole surface."

The floating coat takes only half the material, though nearly double the labour, required for the first coat.

Setting Coat.—Before the floating coat is too dry it is swept over with a birch broom, and when quite dry the third or setting coat is applied, which should be of *fine stuff* for colouring, whitening, or papering, or *bastard stucco trowelled* for painting. *Trowelled stucco* is set with the largest trowel, brought to a smooth face over a surface of 2 or 3 yards, and then worked over with the hand float, at the same time wetting the surface with a brush and floating and sprinkling it alternately until it presents a hard polished appearance, after which it is rubbed over with a dry stock brush.

In order to guard against the setting coat showing numberless fine cracks all over its surface, called *fire cracks*, as frequently happens from the unequal shrinking of the different coats, it should not be applied till the previous coat is quite dry, otherwise, being very thin, it will harden from exposure to the air before that previously laid has done shrinking, the result being that, if there is a proper adherence between the two coats, the setting coat will be disfigured by *fire cracks;* whilst, where the coats have not adhered well together, hollows will be found, and the setting coat will be liable to come off at those spots.

Rendering Walls.—When plaster is applied direct to brick, concrete, stone, or other surfaces than lathing, the first, or pricking-up coat of coarse stuff is called *rendering* instead of *plastering* or *laying*, as in the case of laths. Hence, though the materials employed and method of applying them are identically the same as on lathing, one-coat work is termed *render*, two-coat work *render set*, and three-coat work *render, float and set.*

In rendering brickwork, etc., the mortar squeezed out of the joints during the building of the wall may either be left projecting, or else the joints must be *drawn* or raked out well, as at Fig. 26, p. 51, in order to form a key for the plaster to take hold of, the face of the wall being sometimes picked or roughed over for the same purpose, and the surface must be well brushed and wetted

before any coat of plaster, or more especially of cement, is applied.

When common stucco is used, the walls should be washed over with a liquid wash of stucco, applied with a brush, before the rendering coat is added.

Mouldings, etc.—In the case of mouldings, projecting only 2 or 3 inches, a rough core, or ground on which to run the mouldings, can easily be produced by *dubbing out* in coarse stuff, and, if necessary, driving in a row of nails to take any projecting member; or in cement with pieces of tile embedded in and projecting from it.

When the projection is moderate, spikes driven into the wall, and tow twisted round them, is often considered sufficient; but when the projection is considerable, wooden brackets, roughly cut to the form of moulding required, are plugged to the wall to carry the laths, or a regular framework or *cradling* is made and fixed by the carpenter to receive the lathing and plastering.

The pricking-up is brought to within about $\frac{1}{8}$ inch of the finished surface by what is termed muffling the mould, or covering its cutting edge with plaster of Paris projecting about $\frac{1}{8}$ inch beyond the edge. The mould is made to move straight along the line of moulding by means of a batten or *screed* (sometimes one both at the top and bottom of the mould) temporarily fixed to the wall or ceiling. The muffling is then knocked off the edge of the mould, and a finishing coat of gauged stuff, if for indoor work, is applied, one man laying it on with his *hawk* and *trowel*, while a second man works the mould backwards and forwards, forming the surface and scraping off the superfluous plaster. In very deep mouldings some of the members have to be run separately.

The *mitres* or lines of intersection of mouldings, as in cornices at the angles of a room, are finished by hand with a *joining* tool.

When the mouldings are not continuous but enriched, they can generally be run as continuous mouldings, leaving the enrichments to be added afterwards; these are generally made of plaster of Paris cast in plaster, wax, or gutta-percha, moulds—or, which is better, of some lighter material such as "papier-maché,"—and are secured with plaster of Paris if resting on any projection, or, if not, with white-lead or iron cement, or may be screwed to woodwork, according to circumstances.

Very large projecting mouldings and cornices inside buildings are even made of coarse canvas strained over a light framework and washed over with gauged stuff; they are easily carried up

and fixed in position. Huge cornices of this kind make a great display in the interior of the Albert Hall, South Kensington.

For cement skirtings and other parts liable to injury, either entirely Portland cement, or Portland faced with white cements, such as Parian, Keene's, Martin's, etc., are used.

Fibrous and Patent Plasters.—Fibrous and similar patent plasters may be used with advantage in the finishing and decoration of buildings. They consist of plaster moulded on coarse canvas or wirework, secured to light framing, and are supplied in panels for walls and ceilings, mouldings for cornices, and enrichments of all sorts. They save the mess inseparable from ordinary plastering, whilst the material naturally lends itself to highly decorative panelled work. Though costing more than ordinary plaster, its lightness, being not more than one-third the weight, its freedom from cracking and danger of falling, and the rapidity with which it can be fixed, are all in its favour.

These plasters are manufactured by George Jackson and Sons, 49 Rathbone Place, London, and Hitchin's Patent Plastering Co. St. Mark's Place, Sandringham, Dalston, London.

Scagliola.—Scagliola is a plaster in imitation of marbles, formed of plaster of Paris mixed with some description of size, and different colouring matters stirred through the mass, according to the effect to be produced. White cements, such as Keene's cement, etc., are used for the same purpose, where harder and finer surfaces are required. It is much used in internal decorating for wall panels and pilasters, as well as for imitation marble columns.

Sgraffitto.—This is a description of wall decoration obtained by covering the surface with several coats of plaster, each coloured differently; then by scraping away the top coat or coats the required colour is exposed, as in cutting cameos. A good sample of this kind may be seen on the external walls of the National Training School of Music, next the Royal Albert Hall, South Kensington.

Rough Cast.—Rough cast is a cheap covering used for outside walls, and is often of great service as a protection from the weather. It consists of dashing on to the second coat, which is laid as evenly as possible without floating, while quite soft, a layer of *rough cast* composed of well-washed sand, gravel, or coarse grit of any kind, mixed with pure hot lime in a semi-fluid state, after which it should be at once lime whited or washed over with a coat of some common ochre colour.

Depeter.—Depeter is somewhat similar to rough casting, except that small stones are pressed dry into the soft plaster by means of a board, leaving the surface comparatively rough, and the colour of the stones used; a pleasing effect can often be produced.

Depretor.—Depretor is a term sometimes used to denote plaster finished in imitation of tooled stone.

Pugging.—Pugging consists of a *pricking-up* coat of coarse stuff between the joists of floors, in order to prevent the passage of sound; if on pieces of board or tiles fixed between the joists, it can be done with coarse stuff mixed with chopped hay; and if on laths, with hair mortar, in either case not less than $1\frac{1}{2}$ inch thick. Puddled clay, about 3 inches thick, has been used; but wool made from the slag from iron blast furnaces, which is incombustible and very light, is the best material for such purposes.

Dirty Bricks, etc.—If old materials are used for building purposes care should be taken to prevent dirty sooty bricks being built in any facings to be rendered, as they are almost sure to discolour the plaster, paint, or paper on the walls.

Wash, Stop, and Scrape.—In repairing plaster the surface should be first well washed to remove any colouring, dirt, etc., adhering to the surface; all cracks and holes should be stopped with putty and plaster, and the edges of the new work scraped down to an even surface with the rest of the plaster. If paint has to be removed from plaster it can be done with pumice stone.

Colouring.

The plasterer's trade includes *whitewashing, whitening,* and *colouring, sizing* or *clearcoling,* and *distempering.*

Whitewash.—Whitewash consists of any common fat lime, such as chalk-lime, mixed with water. It is applied with a large flat brush to common walls and ceilings, especially where for sanitary reasons a frequent fresh application is considered preferable to any coating which would last better. It readily comes off when rubbed, will not stand rain, nor adhere well to very smooth or non-porous surfaces. It is cheap, and when used for sanitary reasons should be made up of hot lime and applied at once, under which conditions it also adheres better.

Whitewashing can be done by common labourers, bricklayers' labourers being frequently employed for the purpose; a soldier

should do from 80 to 100 yards super per diem. One-coat work requires about $1\frac{1}{2}$ cubic foot or $1\frac{1}{6}$ bushel of slaked lime per 100 yards super; for two-coat work about 2 cubic feet or $1\frac{3}{5}$ bushel will suffice.

Common Colouring.—A cheap colouring coat is formed by mixing any common ochres with the whitewash; to which may be added 1 pound of Russian or pure tallow per bushel of lime, stirred in while hot from slaking, which makes it more durable, especially for outside work; or, better still, 2 pounds common salt, 1 pound sulphate of zinc, and 2 gallons of skim milk.

Size, or Clearcole.—*Size* is merely liquid glue, being generally prepared by boiling down the sinewy and horny parts of animals, the strongest being obtained from the oldest animals. It is mixed with whiting and other colouring matters to make them adhere to surfaces without rubbing off as readily as whitewash does.

Double size is merely a stronger concoction obtained by boiling it down to about half the quantity.

Claircole or *clearcole* is size used by itself as a *priming* or first coat, to fill up or cover over the surface of a porous material like plaster.

Patent size is a gelatine, and can be mixed without any soaking as required for glue size.

In good work the pores of plaster should always be stopped with a coat of clearcole before applying any colouring coat. One colouring coat will have a better appearance when so treated than two coats applied without the clearcole.

Whiting.—Whiting is merely pure chalk ground to a fine powder; it is chiefly used with water and size for *whitening* or *distempering* ceilings and walls within buildings, and sometimes for common external work, though it will not last long exposed to the weather. The best method of mixing it is in the proportion of 6 lbs. of whiting to 1 quart of double size, the whiting to be just covered with cold water for six hours, then mixed with the size and left in a cold place till it becomes like jelly, in which condition it is ready to dilute with water and use. It will take 1 lb. of jelly to every 6 superficial yards.

Distemper.—*White distemper* is whiting and size; whatever colouring matter is added should be ground in water and added to the whiting before it is mixed with the size. If one coat of buff colour and size is required the specification would say "once distemper buff."

White-lead or sulphide of zinc white, if used instead of whiting, produces a smoother surface but is more expensive.

Washable distempers are referred to on page 300.

Common and Superior Colours.—*Common colours* in both plasterer's and painter's work include lamp-black, red and white lead, and common ochres, such as grays, buffs, stones, etc.

Superior or *fine colours* include bright yellows, warm tints, cloud colours, common greens, blues, pea greens, rich reds, pinks, and verditer; the last five being generally classed as delicate tints and charged at a higher rate.

Fresco.—This is a method of water-colour painting on fresh plaster, in which the colours, being absorbed by the plaster, do not get destroyed by the action of the atmosphere so rapidly as if they were merely laid on the plaster when dry. Fine specimens of high-art fresco painting are to be seen in the Houses of Parliament, but it has been found necessary to protect the frescoes with glass, in order to preserve them from the destructive effects of the London atmosphere; in fact, there is no doubt that fresco painting never can be brought to such perfection in this damp climate as it has attained under the summer sky of Italy.

Measuring and Estimating Plasterer's Work.

Plastering of all kinds, as well as lathing, is paid for by the yard super, the prices varying with the materials employed, the nature of the finished face required, and whether the work is straight or curved; the only exceptions being small pieces, narrow widths, and mouldings, which are charged by the foot super, or by the foot run in the case of very narrow widths.

Ornamental parts are paid for separately by the foot super, foot run, or by the number, according to their nature.

Colouring large surfaces is paid for by the yard super, narrow widths by the run, and isolated pieces by the number.

For the application of these rules to particular cases see the War Department Schedules, Laxton's, or any other price book.

Measuring.—In measuring ceilings take from wall to wall, less one projection of cornice, and then take all deductions. Take mean length of cornices, etc., by taking from out to in, and by the girth, wherever the mould has been run; either numbering the mitres or taking them by the foot run. In the case of

enrichments take them separately, in addition to the feet super of plain cornice.

Plastering on walls is measured from the top of grounds, or cement skirtings, to foot of cornice, and on laths add one-third the height of the cornice for stucco, and two-thirds for laid and floated work.

Estimating, Materials, etc.—The plasterer is attended by a labourer who mixes and keeps his board supplied with materials, and generally by a boy called a *hawk-boy,* who feeds his hawk from the board.

A plasterer, labourer, and a boy, can *lath, lay, and set* about 20 yards per diem, or *render set* about 30 yards per diem.

Scaffolding is not generally charged extra in new work, but must be taken into account in estimating any repairs which cannot be done from the ordinary trestles and boards used by the plasterer; the rule being to charge for scaffolding when the hawk cannot be fed from the ground.

The amount of materials required for the different operations are given in Hurst's *Handbook,* as well as in price books such as Laxton's and Kelly's, but the annexed table, which has been carefully compiled from practical observations, will furnish most of the required information :—

PLASTERER.

Analysis of Materials and Cost.

Materials and labour required for 10 yards superficial.		Render one coat, and set with fine stuff.				Render float, and set with fine stuff.				Lath, plaster, and set with fine stuff.				Lath, plaster, float, and set with fine stuff.				Render, float, and trowel with 1 part Portland cement to 2 parts sand.			
Description.	Value.	Quantity.	£	s.	d.	Quantity.	£	s.	d.	Quantity.	£	s.	d.	Quantity.	£	s.	d.	Quantity.	£	s.	d.
Portland cement, bushel	2/6	...		...		...		...		...		...		...		...		2½	0	6	3
(Chalk) lime, ft. cu.	–/4	5	0	1	8	6¼	0	2	1	5½	0	1	10	6¾	0	2	3	...		...	
Sand, ft. cu.	–/1½	5	0	0	7½	6¼	0	0	9¼	5½	0	0	8¼	6¾	0	0	10	...		...	
,, washed, ft. cu.	–/3	...		...		...		...		...		...		...		...		6	0	1	6
Hair dried, lbs.	–/3	2½	0	0	7½	3	0	0	9	2¾	0	0	8¼	3¼	0	0	9¾	...		...	
Plasterer, days	5/6	⅓	0	1	10	½	0	2	9	½	0	2	9	¾	0	4	1½	1¼	0	6	10½
Labourer, ,,	2/9	⅓	0	0	11	½	0	1	4½	½	0	1	4½	¾	0	2	0¾	1¼	0	3	5¼
Boy, ,,	1/6	⅓	0	0	6	½	0	0	9	½	0	0	9	¾	0	1	1½	...		...	
Water, gallons	...	20	0	0	1	25	0	0	1	22	0	0	1	27	0	0	1	15	0	0	1
Laths(one and half) bundles	2/–	...		...		...		...		2¼	0	4	6	2¼	0	4	6	...		...	
Nails, cast, lbs.	–/1½	...		...		...		...		4	0	0	6	4	0	0	6	...		...	
Cost, per 10 yards,	...	...	0	6	3	...	0	8	6¾	...	0	13	2	...	0	16	3½	...	0	18	1¾
,, per yard,	...	...	0	0	7½	...	0	0	10¼	...	0	1	3¾	...	0	1	7½	...	0	1	9¾

CHAPTER VII.

PLUMBER'S WORK.

THE plumber's trade in the War Department Schedules comprises all the work connected with the laying or fixing of sheet-lead or zinc in roofs, gutters, cisterns, etc.; the fixing of lead, zinc, composition or iron pipes for water, steam, or other purposes, together with all the necessary fittings, such as cocks, etc.; also the fixing and fitting up of pumps, water-closets, urinals, baths, etc.

Tools.

The special tools used by the plumber, besides such ordinary ones as *hammers, chisels, files,* and *gauges,* are as follows:—

Mallet, which is tapered on one side, both faces being rounded; whereas the tinman's mallet is the same on both sides with flat faces.

Bat or *dresser,* made of box or beech, about 18 inches long, for *dressing* and *bossing up* (thickening or setting up) sheet-lead.

Chase-wedge or *set,* which is a wedge made of box or beech, with a short handle for holding and striking, used for dressing lead into angles, the thin edge of the wedge being about 4 inches long.

Turning-pin or cone, of beech or box, for widening the mouths of pipes.

Mandrils, or wooden cores of sizes, for moulding the lead round, in forming pipes out of sheet-lead.

Draw-knife, for cutting lead.

Shears, both *stock* and *scotch,* the former large and the latter small shears, for cutting sheet-metal such as zinc, tin, copper, etc.

Scraper or *shave-hook,* which is a sharp-edged triangular piece of steel, each side being about 2 inches long, set at right angles to a handle fixed at the centre, and used for scraping and finishing off joints.

Fire-grate or *furnace,* for melting solder and heating irons.

Pot and *ladle,* for heating and holding solder.

Soldering tools, consisting of—*soldering irons,* also called *grozing*

bossing, or *round irons,* with an iron bulb at one end and a hook at the other for hanging on to the furnace; used for supplying heat in finishing joints with coarse molten solder.

Copper bits or *bolts* of iron tipped with copper, for use with fine or solid solder, and either straight, with a pointed end, or hatchet-shaped at the end; the hatchet bolts are essentially the plumber's, and the straight bolts the tinman's and gasfitter's tools.

Linen ticking or *soldering cloths,* for wiping joints, as in jointing pipes.

Blow-pipes, and *rushes* for using with them, are also required, when, as in R. E. Companies, plumbers are called upon to do such work as joining or repairing composition or white metal pipes, which are used as gas-pipes, speaking-tubes, and sometimes as water-pipes. For self-acting blow-pipes see p. 261.

Materials.

Sheet-Lead.—The lead used by the plumber is chiefly *sheet-lead,* either *milled* or *cast.*

Milled Lead is rolled out in a mill into thin sheets, from about 6 to 9 feet wide up to about 35 feet long, and is sold in rolls.

Sheet-lead is always described in lbs. per foot super; thus 5 lb., 6 lb., or 7 lb. lead implies sheet-lead weighing 5, 6, or 7 lbs. per foot super. The weight of milled sheet-lead runs from 1 to 12 lbs. per foot super, and the thickness it should gauge may be taken at ·017 of an inch for every lb. per foot super.

Where a heavy lead is not required to resist the ripping action of the wind, or the wear and tear of walking over it, the lighter qualities may be safely used; the thinner the sheets are the denser the lead is likely to be, owing to the extra rolling required to reduce their thickness.

Cast Sheet-Lead runs up to about 6 feet in width and 18 feet in length. The plumber often casts it himself out of old lead, taken in exchange, and the cuttings which accumulate in the course of his work. Cast lead, being harder, will stand more wear, but, being subject to flaws and air-holes, is not so reliable as milled lead, and should not be used of a lighter gauge than 6 lbs. per foot super. It is not so pliable nor so smooth on the surface or uniform in thickness as milled lead.

Lead Pipes.—Lead pipes of a large size are made by the plumber out of sheet-lead dressed round a wooden core or

mandril, and soldered up. The smaller-sized pipes were formerly cast in short lengths of about three or four times their ultimate thickness, and then either *drawn* or *rolled* out to the required thickness. Now, however, they are formed in long lengths of the required size by pressing molten lead through a circular hole in the receptacle in which it is kept fluid, a round core being fixed in the centre of the aperture, leaving an open ring all round it, through which the lead is squeezed, hardening as it comes in contact with the external air; it thus forms a continuous pipe, the length of which is only limited by the capacity of the vessel containing the lead.

Special shaped pieces of lead piping, such as syphons, etc., can now be obtained cast, at a less cost than they can be made up out of sheet-lead.

The following lists, compiled from different Lead Merchants' Trade Circulars, give the principal sizes, weights, and lengths of water and soil pipes and composition gas tubing procurable ; subject, of course, to variations due to improvements in manufacture, or special trade requirements :—

DRAWN LEAD WATER-PIPES AND BARRELLING.

Inside Diameter.	**Light** per Yard.	**Middle** per Yard.	**Stout** per Yard.	Extra Sizes. Weight per Yard.	Average Length.
Inches.	Lbs.	Lbs.	Lbs.	Lbs.	Yards.
$\frac{3}{8}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	3, 4, 5, $5\frac{1}{2}$	50
$\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{1}{2}$	3, 4, 5, 6, 7, 8	45
$\frac{5}{8}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{2}$	7, 8	36
$\frac{3}{4}$	6	$7\frac{1}{2}$	9	5, 7, 8, $8\frac{1}{2}$, 10, 11, 12	24
$\frac{7}{8}$	7	$8\frac{1}{2}$	10	...	22
1	8	10	12	7, 9, $9\frac{1}{2}$, 11, 15	20
$1\frac{1}{4}$	11	13	15	9, 10, 12, $12\frac{1}{2}$, 16	14
$1\frac{3}{8}$	13	$15\frac{1}{2}$	18	...	12
$1\frac{1}{2}$	14	$16\frac{1}{2}$	19	12, $15\frac{1}{2}$, $17\frac{1}{2}$, 18, 21	10
$1\frac{3}{4}$	15	18	22	$15\frac{1}{2}$, 17, $18\frac{1}{2}$	10
2	20	25	30	19, 23, 26	6
$2\frac{1}{4}$	25	30	35	...	5
$2\frac{1}{2}$	30	35	40	26, 27	4
3	32	42	52	36, 44	4
$3\frac{1}{2}$	46	51	56	45, 49, 52	4
4	52	63	74	48, 57, 61	4
$4\frac{1}{2}$	60	70	80	...	4
5	73	...	84	...	4
6	78	...	92	...	4

DRAWN LEAD SOIL-PIPES.		PATENT COMPOSITION GAS TUBING.		
Inside Diameter.	Equal to Sheet-lead of	Inside Diameter.	Per Yard.	About Average Length.
Inches.	Lbs. per ft. super.	Inches.	Lbs.	Yards.
$3\frac{1}{2}$	5, 6, 7	$\frac{1}{4}$	$\frac{3}{4}$	110
4	5, 6, 7, or 8	$\frac{5}{16}$	1	90
$4\frac{1}{2}$	6, 7, or 8	$\frac{3}{8}$	$1\frac{1}{4}$	70
5	6, 7, or 8	$\frac{7}{16}$	$1\frac{1}{2}$	60
6	7, or 8	$\frac{1}{2}$	$1\frac{3}{4}$–2	40
...	...	$\frac{9}{16}$	2–$2\frac{1}{2}$	35
...	...	$\frac{5}{8}$	$2\frac{1}{2}$–3	30
...	...	$\frac{3}{4}$	3–$3\frac{1}{2}$	25
...	...	$\frac{7}{8}$	$3\frac{1}{2}$–4	22
...	...	1	4–5	20
...	...	$1\frac{1}{4}$	$6\frac{3}{4}$–9	18

Zinc.—Zinc, which, bulk for bulk, is about three-fifths the weight of lead, is mixed with copper to form brass; it is brittle both at ordinary and at high temperatures, but malleable at 200° to 250° Fahr., when it can be rolled into sheets, which, when cool, become tough, and retain to a great extent their malleability. At a red heat zinc is inflammable and blazes fiercely (Bloxam on Metals).

The best zinc is supplied to the market by the Vieille Montagne Company, in sheets rolled 7 feet long by 2 feet 8 inches and 3 feet wide, and 8 feet long by 3 feet wide, but can be supplied up to 12-feet lengths at an extra price.

It is economy to use only the very best zinc, and if there is much to be laid, to employ the Company's agents (Fred. Braby and Co., Fitzroy Works, Euston Road, London, are the London agents), or at any rate to get their illustrated book of instructions, and to insist on the work being carried out in accordance therewith, as its durability depends on the sheets not being pierced by nail-holes, their being free to expand and contract, as well as in avoiding any galvanic action being set up from the presence of moisture when in contact with other metals, such as lead, copper, iron (unless galvanised), or contact with lime, though neither Portland nor Roman cement will injure zinc.

Good sheet zinc is uniform in colour and should stand bending backwards and forwards without cracking; its tenacity is five times that of lead and three-fourths that of copper.

The surface of pure zinc gets gradually covered with a protecting coat of gray oxide of zinc, the process ceasing altogether after about four years.

Roofs covered with zinc forty years ago in Portsmouth dockyard, and fifty years ago at Canterbury Cathedral, are still quite good.

Inferior zinc is spotty and darker in colour than pure zinc, and is not durable if exposed to sea air and smoky atmospheres, as soot with moisture will gradually eat holes through it. Cats should be kept off zinc roofing, as their urine will destroy it.

Zinc Gauges.—The different thicknesses of zinc are known by its weight per foot super; those recommended by the Vieille Montagne Company for roofing purposes are, using their new gauge, No. 14, of $18\frac{3}{4}$ oz. to the foot; No. 15, of $21\frac{3}{4}$ oz.; No. 16, of $24\frac{3}{4}$ oz. Nothing less than $21\frac{3}{4}$ oz. should be used for flats.

All manufacturers of zinc do not adopt the same gauges; thus, with some, No. 12 = 18 oz.; No. 13 = 20 oz.; No. 14 = 25 oz.; whilst by the old Belgian gauge, No. 12 = 18 oz.; No. 13 = $19\frac{1}{2}$ oz.; No. 14 = $21\frac{1}{2}$ oz.; No. 15 = 24 oz; and No. 16 = 26 oz.

Solder.—The solders used differ considerably in practice, according to the fancy and skill of the workman and the purpose for which they are required; hence the difference between the ingredients of solders as laid down in Hurst's, Molesworth's, and other pocket-books, in which certain proportions of tin and lead (each author giving different proportions) are said to constitute plumber's solder.

The term *brazing* or brass-soldering properly implies soldering with the constituents of brass (zinc and copper), but is commonly applied to the process of soldering with any hard solder.

The terms *hard* and *soft* indicate the relative hardness of the amalgams; hard and coarse are, in some cases, equivalent terms to soft and fine, though not with the soft solders, since the harder metal tin is finer or more fusible than the softer metal lead.

The following solders are those in ordinary use, their *coarseness* and *fineness*, depending on the temperature at which the metals employed will fuse:—

TABLE OF SOLDERS.

Metals to be United.	Description of Solder.	Ingredients and Melting Points in degrees Fahr.				How Melted.	Fluxes Employed.	Remarks.
		Tin.	Bismuth.	Lead.	Melting point of Solder.			
		442°	507°	620°				
	Soft Solder.							
Pewter	Pewterer's fine	2	1	1	201° B[1]	By tinned copper bit or blow-pipe	Gallipoli oil.	Zinc is difficult to solder neatly.
	,, coarse	1	$\frac{1}{4}$	1	320° H[1]		,, ,,	
Hard pewters Britannia metal, tin, zinc, brass, copper	Tinman's very fine	4	...	1	320° B	,, ,,	Rosin or sal-ammoniac; and for zinc, chloride of zinc, or Baker's fluid.	Chloride of zinc, or "killed spirits," is spirits of salts (hydrochloric acid) saturated with zinc.
	,, fine	3	...	1	356° H	,, ,,		
	,, ordinary	2	...	1	372° B	,, ,,		
Lead	Plumber's fine	1	...	1 to $1\frac{1}{2}$	385° B	,, ,,	Rosin.	Iron to be soft soldered must be first tinned.
	,, ordinary or pot metal	1	...	2	441° H	The pot or ladle, and with soldering iron	Tallow.	
	,, coarse	1	...	$2\frac{1}{2}$ to 3	482° H	,, ,,	,,	Solder for use with the copper-bit is cast in strips called "strap solder," or in thin cakes for gasfitter's work.
		Silver.	Copper.	[1] B = Bloxam on metals. H = Holtzapffel, vol. i. chap. xxi., on Soldering.				
		1873°	2000°					
	Silver Solder.							
Silver, brass, copper	Soft	2	1[2]			By blow-pipe or on open hearth with blast	Venice turpentine for silver. Borax for brass, etc	Plumber's "working solder," or "pot metal," sold in ingots, assayed and stamped by the Plumber's Company, is known as "Plumber's Sealed Solder."
	Hard	3 or 4	1[2]					
		Tin.	Zinc.	Antimony.	Copper.			
		442°	758°	800°	2000°			
	Brazing.							
Brass, copper	Very fine	2	...	1	—	,, ,,	Chloride of zinc, spirits of salts, sal-ammoniac, borax.	[2] One brass wire in place of one copper adds softness, and with two silver is used for soldering silver.
	Fine	1	3	...	4	,, ,,		
	,,	1	...	...	2	,, ,,		
	Soft spelter	...	1	...	1	,, ,,	,, ,,	
Copper, iron, steel	Hard spelter	...	1	...	$1\frac{1}{2}$ to 3	,, ,,	,, ,,	

The above solders are not all required for plumber's work proper, but are given here as plumbers in R. E. Companies are called upon to do a good deal of what is, more strictly speaking, tinman's, coppersmith's, and gasfitter's work.

For joints which can be run rapidly, or where the solder can be used in quantity, and so hold the heat better, a *coarse* and less expensive solder (lead predominating) can be used, whilst softer or *finer* solders (with more tin and less lead) which hold the heat better, or remain in a state of fusion at a lower temperature, must be used when the operation is of necessity longer, or the solder is used in small quantities. For this reason a quick hand can use a *coarser* and less fusible solder than a slow hand.

Two lead to one tin is called plumber's solder or *pot metal*, as it has to be fused on the fire under considerable heat; it is used for gutter work, cisterns, jointing pipes, etc. The *finer* or more fusible soft solders, containing a greater proportion of tin, are used where less heat is available, as with the copper bolt or bit.

Three tin to one lead is mostly used when a very fusible alloy is desired, a little bismuth greatly increasing the fusibility; but only so much of the more expensive metal should be used as is necessary to make a workable solder fit for the purpose required. A good plumber can tell very closely from the colour of his solder, which varies according to the way in which it is cooled, the relative proportions of its constituents.

Avoid ready-made solders, as you cannot depend on the alloy—too much lead, which is cheaper than tin, is almost sure to be put into plumber's solder—besides which there is always plenty of scrap lead about, which can be used for the purpose.

Where much soldering is to be done the plumber starts with a little excess of tin, as by degrees the solder picks up lead from the lead on which it is used, which reduces its fusibility. Zinc getting into plumber's solder makes it too *brittle;* but foreign matter, such as zinc, if only present in a small quantity, can be burnt out by letting the pot get red hot till it goes off in vapour and scum which can be skimmed off the top.

Flux.—The different fluxes used for soldering both assist the fusing of the solder and keep the heated surfaces of the joint clean and free from oxides.

Red and White Lead.—Red and white lead are used by plumbers for making joints which cannot well be got at to solder, as well as for such work as fixing cocks, etc.

Operations of Soldering.

The solder must fuse more readily than the metals to be united, and must match them in colour, if the joint is not to show.

In making a junction where neither colour nor strength has to be considered, either ordinary or fine tinman's solder is used; but if the strength of the metal is to be called into play, the solder must be as nearly as possible equal to it in strength.

The metal surfaces to be united must be scraped clean and bright wherever the solder is required to adhere. In leadwork the bright surfaces are at once protected by a coating of grease or tallow, and to prevent the solder from adhering to the metal beyond the joint the surface is smeared with *soil* or *smudge* (as at A, Figs. 265, 266) a mixture of size, lamp-black, and chalk, boiled together with water or stale beer.

In *soft soldering* the flux may be either smeared or sprinkled on the surfaces of the joint, and solid or stick solder run along it with a blow-pipe, or more generally with the copper-bit, which supplies heat enough for uniting small surfaces and the edges of thin sheet-metal with solders not coarser than plumber's fine solder. The copper nose or point of the bit is *faced* or *tinned*—*i.e.* coated with the solder with which it is to be used; it must never be made red hot, or it will require refacing.

Plumber's pot-metal solders are first melted and then run on to the joint with a ladle, the joint being formed and finished by wiping or smoothing it round with a well-greased soldering cloth, and the soldering or round iron raised to a dull red heat.

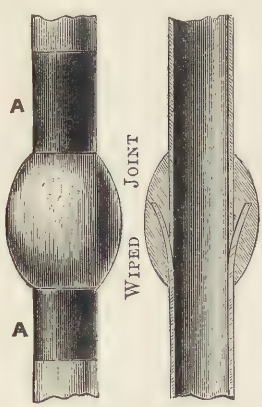


Fig. 265.

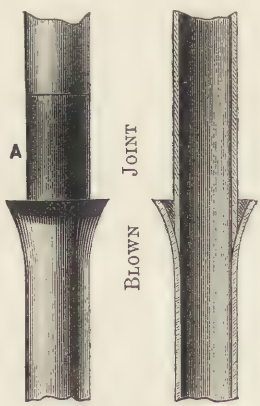


Fig. 266.

Wiped and flanged joints (Fig. 265) being much stronger than blown joints (Fig. 266), should always be used for pipes under pressure. In both cases the end of one pipe is rasped to a fine edge and then inserted in the other, which is more or less

trumpet-mouthed to receive it. The inserted end should always point in the direction of the flow in the pipe, to prevent the current being checked, or solid substances being caught against the edges.

Fig. 266*a* gives sketches of *clear bore* joints (Patent Joining Lead Pipe Company, Manchester), formed by drifting out the ends of the pipes sufficiently to admit short brass lining tubes, equal in bore to the pipes themselves, the ends of which are rasped back inside and kept a little apart, leaving a small space to be run in with solder. These joints are easily and cheaply made, though more adapted to shop work than to pipes in position, as they involve the use of purpose-made moulds for the different joints and sizes of pipes. They are neater and stronger than ordinary joints, and prevent a careless or unskilful workman choking the pipe with solder.

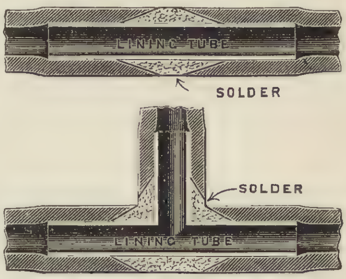


Fig. 266*a*.

In *silver soldering* and *brazing* the harder metals, the solder is placed on the joint either in little lumps or in a granulated form, as with the spelter solders, or as a powder, the flux being either mixed with or sprinkled over the solder. Heat is then applied with a blow-pipe, or, for large joints, in a smith's fire until the flux acting on the solder causes it to fuse suddenly and run into the joint, uniting the surfaces together.

A good joint for fine brasswork is made by scraping the surfaces bright, smearing them with a strong solution of sal-ammoniac, placing a piece of tinfoil between them, and then applying just sufficient heat to fuse the tinfoil.

The self-acting blow-pipe invented by Mon. Costa is stronger and steadier than the ordinary pipe, and leaves both the operator's hands free. They cost 3s., 4s. 6d., and 6s. 6d., and are used with a candle, gas jet, or lamp. A strip of tin or brass on which solder has been melted can be used instead of a soldering iron; it will retain its heat by keeping part of it exposed to the blow-pipe flame while soldering, thus combining the advantage of very fine jointed soldering bolts with the heat-retaining properties of soldering irons.

Execution of Plumber's Work.

Laying Lead.—The chief points to be attended to in laying sheet-lead is to dispense, wherever practicable, with soldered joints,

which are always weak points and liable to leakage, and to leave it as free as possible to expand and contract with alterations in the temperature; consequently all nailing or rigidly fixing the edges should as far as possible be avoided, and, moreover, the sheets should not be laid in too great lengths—12 feet is a maximum, 10 feet is better—otherwise the lead will get loose from constant dragging and buckling.

In order to let the water run off, sheet-lead should be laid to a *current* of not less than 1 inch in 10 feet, and at that fall care must be taken to get a very even surface to lay it on.

Lead should not be laid in contact with oak unless the latter is quite dry and free from sap, otherwise the gallic or acetic acid in the wood will turn the lead into acetate of lead, or ceruse.

Lead-headed Nails.—When iron nails are used in fixing lead-work, their heads should be dipped into molten lead, in order to protect them from the atmosphere; nails so treated are called *lead-headed nails.*

Lead Dots.—A good method of securing nails to woodwork, as well as protecting them from weather, is, wherever a nail comes, to hollow the wood out slightly, dress the lead into the hollow, drive the nail in through the centre of the hollow, and then fill up level with solder. The same may be done without hollowing out, but then the *lead dot* covering the head will project above the surface of the leadwork. Screws used in this way, in place of nails, render the work very secure.

JOINTS.—With the object of avoiding the use of solder, one of the following joints is used by plumbers, according to its position—namely, a *lap joint,* a *roll,* or a *drip.*

Lap Joints.—In a lap joint one sheet of lead overlaps that next to it, in which case the overlap should not be less than 4 inches, and such a joint should not be used much out of the vertical, if in the direction of the current; or if at right angles to the current, on a flatter incline than 1 in 6.

Rolls.—The roll is used for joints running in the direction of the current, along a watershed, or the line of intersection of two inclined planes, as across the highest point of a gutter falling both ways, as well as for fixing lead in such places as on the hips and ridges of roofs.

The smallest and neatest roll is made by turning up the edges of the sheets, one edge being the higher of the two, which is bent

over the other, and the two are then turned round into the form of a roll, either solid or hollow, as shown in Fig. 267, *a* and *b*.

The commoner and easier method is to dress the two edges round a wooden roll from $1\frac{1}{2}$ to 3 inches wide, as shown in Fig. 268. The lead should not be continued, as shown by the dotted line, as the end *a* is sure to buckle-up from the expansion and contraction of the metal, giving the wind a fair chance of getting under and loosening the joint, as well as of driving wet into it, which would be greatly assisted by capillary attraction.

Fig. 269 shows how lead is fixed round a roll on hips and

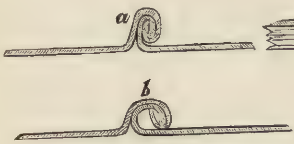


Fig. 267.

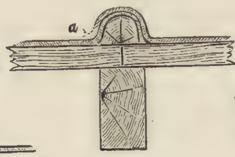


Fig. 268.

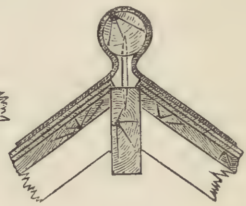


Fig. 269.

ridges; it is often further secured by lead-headed nails driven through the lead into the roll; but, however well done, they are sure to work out under the constant expansion and contraction of the lead; screws will hold the lead, but they are seldom used on account of the cost.

Instead of dressing the lead round a ridge roll, as in Fig. 269—in which case it is safer to use a heavy lead, say 7-lb. lead, in order to guard against its being blown off by the wind, since nails are not long to be depended on—a far better and safer plan is to

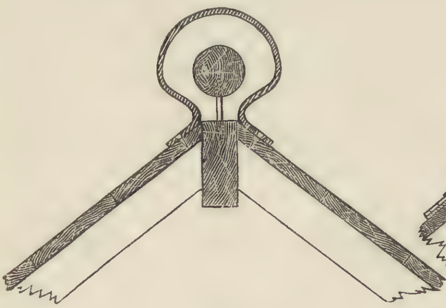


Fig. 270.

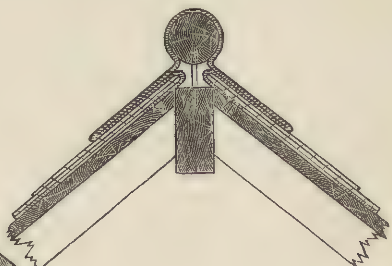


Fig. 271.

take a piece of, say 4-lb. sheet-lead, nearly 2 feet wider than would ordinarily be required, nail it down at both edges, and

leave it standing up, as in Fig. 270, until the slating is laid, when it may be dressed down, as in Fig. 271. When so fastened the nails cannot work loose, the lead is free to expand and contract, and no nail holes are exposed to the weather.

Drips.—Drips are used when joints in the lead run across the current, instead of with it, and therefore in long falls, as in lead gutters and flats, a drip must occur at about every 10 feet, in order to prevent the lead being laid in too long lengths; but if the fall is greater than 2 inches to 1 foot, a lap joint may safely be used in place of a drip.

Fig. 272 is a section of drips as commonly used in gutters,

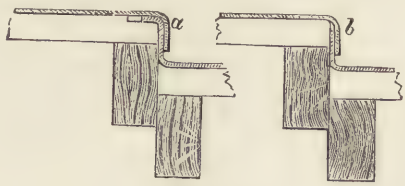


Fig. 272.

though the cross rebate cut in the boarding at *a*, to allow of the under lead turning over without forming a ridge to keep the water back, is both unnecessary and wasteful of lead. It is better simply to turn the lead up, as at *b*, not allowing the upturned edge to run closer to the top of the drip than $\frac{1}{4}$ inch. The minimum depth of a drip should be 2 inches. The overhanging lead should be kept about $\frac{3}{4}$ inch above the sole or bottom of the drip, to guard against the water being drawn up under the lead by capillary attraction.

Piglugging and Bossing.—Instead of cutting out and welding vertical and other angles, as to gutters, a *welt* or *piglug*, also called a dog-ear, joint is often formed by folding and doubling the angle back, as shown in Fig. 273.

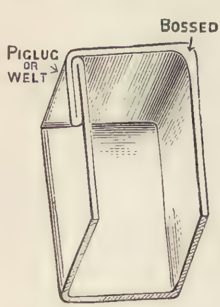


Fig. 273.

A neater, though a more difficult way of forming the same angle, is by *bossing* or *setting up* the lead; in fact diminishing it in length by knocking it together and thickening it. This has also to be done on the inside sweep of curved pipes made out of sheet-lead, and is one of the most difficult operations a plumber has to perform.

Flashings.—When the edges of sheet-lead are turned up, as

in gutters, against the side of a chimney shaft or against the back of a blocking course, instead of their being fixed by being turned into the joints of the brickwork—or into a groove or *raglet*, about an inch deep, in stonework—the edges should be left free and a *flashing*, or narrow strip of lead, for which 5-lb. lead will do, is secured along one edge, in the joints or raglet, the other end being bent over the upturned edge of the gutter lead, which it should overlap about 4 inches; thus one edge of each piece of lead is left free to expand and contract.

The lead flashing or *apron* (the name given to the piece which hangs over and covers the upturned edge of the lead, whether in gutters, flashings, or elsewhere) is secured, in Fig. 274, by being burnt in, or run with lead into the groove in the top of the blocking course, the lead being finally caulked or punched into the groove.

At *b*, Fig. 274, it is tucked into the joints of the brickwork,

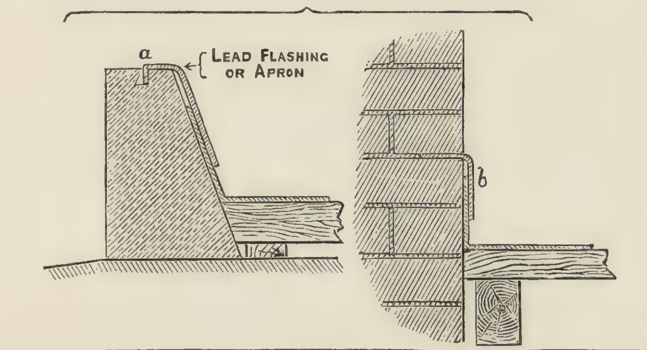


Fig. 274.

which are raked out for a depth of about 2 inches, and wedged in with small plugs of fir or hard wood, or iron holdfasts or wall hooks, which are better galvanised, the joints being filled in with cement, to which 2 of sand should be put to prevent shrinking; lime mortar would eat into the lead, as well as into zinc.

In tucking lead, laid on the rake, into the joints of brickwork, it should be *stepped*, as shown in Fig. 275, each step being cut back so as to keep out the weather better.

Zinc being cheaper is sometimes used for flashings, though not nearly so durable as lead, but, as already stated, zinc and lead should never be placed in contact.

Soakers.—Separate pieces of lead, called *soakers*, cut to the

length of the slates, but slightly broader, are frequently worked in with them for about half their width, the rest being turned up against the wall and covered by a raking or step flashing, as the case may be. They are seldom used in England, since they run into more lead than the ordinary method.

Tingles.—In order to guard against the wind getting under

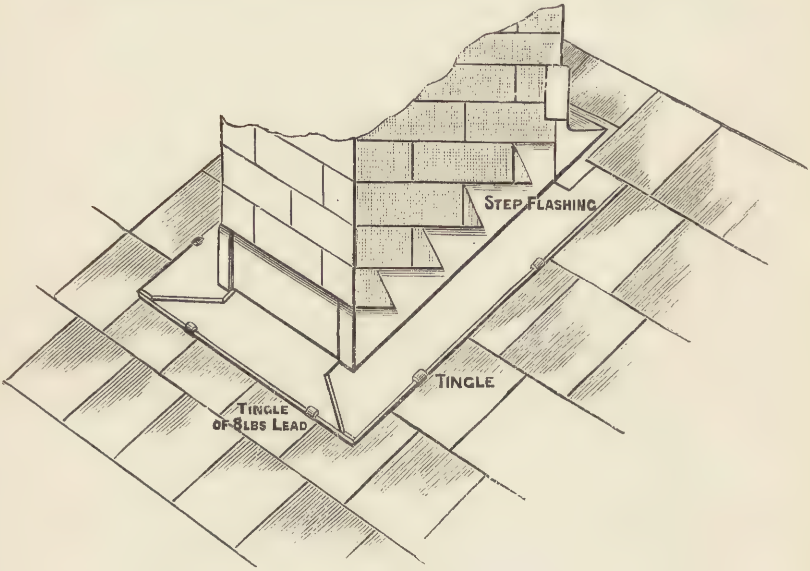


Fig. 275.

and disturbing flashings, where they lie, as in Fig. 275, overlapping the slating, clips or strips of stout, heavy, lead, called *tingles*, are often used, one end being nailed to the boarding beneath, or hooked on to the head of a slate, and the other clipped over the lower edge of the flashing.

Measuring Plumber's Work.—In measuring sheet-lead work, the net amount of lead used is measured and charged for by the cwt. or the lb., as the case may be, including cutting to dimensions, laying, fixing, and nails.

Sheet-zinc work is paid for by the foot super.

Lead pipes are valued either by the cwt. or the foot run.

In giving old lead in exchange, it is allowed for by weight, a deduction of 6 lbs. per cwt. being ordinarily made for dirt.

A great proportion of plumber's work is jobbing, which has to be paid for by valuing the labour and materials separately.

CHAPTER VIII.

PAINTER'S, GLAZIER'S, AND PAPER-HANGER'S WORK.

ALTHOUGH the Painter, Glazier, and Paper-hanger are all included in the War Department Schedules under the head of a single trade, and the work of all three is frequently performed by the same workmen, still, for the sake of convenience, they will be described separately.

PAINTER.

Painter's work chiefly consists in applying an impervious coat, of which some drying oil is the base, to the exposed surfaces of the materials used for building purposes, either as a preventative against decay, or for ornamental purposes, or both of these reasons combined. In external work the chief use of paint is to protect the material beneath from the destructive influence of alternate wet and dry, wet and frost, the sun's rays, and the many acids present in the atmosphere, especially of large towns. In internal work it is principally employed for decorative purposes.

If wood is not properly seasoned and free from moisture, any waterproof coating, such as paint or varnish, by confining the moisture in its pores, will lead to its decay from dry rot. Where durability need not be sacrificed to appearance, the rough surface, as left by the saw, is the best for resisting the alternate wet and dry, which is so destructive to external woodwork.

Tools.

The principal tools used by the painter are as follows:—

Grinding stone, 1 foot 6 inches to 2 feet square, generally of marble; and *muller,* about 7 inches long and 4 inches diameter, of granite or some hard pebble, for grinding colours.

Earthenware and *tin pots,* for holding colours, and *tin cans* for oil and turpentine.

Pallet, to hold small quantities of colour for letter and decorative painting.

Pallet knives, 9 and 15 inches long, for working up and scraping off colours on the pallet and grinding stone.

Stopping knife, 6 or 7 inches long and slightly pointed, for pressing putty into cracks, nail holes, etc.

One pound dusting brush, unground, marked with 000 on handle.[1]

One pound painting brush, ground, marked with 000 on handle.[1]

Six or eight *sash tools* or smaller brushes, for *cutting in* paint to glazed sashes.

Sable-hair pencils, for letter painting.

Flat hog's-hair brushes, steel combs of different degrees of fineness, *sponges,* etc., for graining.

Pumice stone, for smoothing the surfaces before applying a fresh coat of paint.

Materials.[2]

The painter either covers over and hides altogether the surface below with an opaque coat called paint—for which purpose a mixture of white-lead and linseed oil, with or without any colouring matter, is commonly used—or he covers the surface with some transparent coat, such as linseed oil or some varnish, allowing the grain below to show, the wood frequently being previously stained in order to heighten the effect.

The principal materials employed, upon the quality and proper application of which the durability and appearance of painter's work depends, are comprised under the following heads, viz. :—

Vehicles or liquids capable of holding colouring matters or *pigments* in suspension, and distributing them evenly over the surfaces to be treated. They consist of water for water-colours, whether applied to pictures or in the form of whitewash or distemper to walls; and, for oil-painting, of fixed or fatty oils

[1] These brushes used to weigh 1 lb. The hairs are merely cut to the required length at the ends, but for painting are afterwards *ground* or rubbed down on a stone, to fine off the square ends of the bristles.

[2] For further information on the subject of painter's materials, see "Painting" (Virtue and Co.'s Series), *Manual of House Painting,* by Ellis A. Davidson; the *Decorator's Assistant,* by A. J. Barnes and Co.

(fixed, as distinguished from volatile oils, are incapable of being distilled), which must also be drying oils, capable of filling up and hardening in the pores of the material to be painted, as well as forming a durable coating over the surface; or else of volatile or essential oils, either mixed with fixed oils, merely to dilute the paint, or used as vehicles by themselves.

Driers or oxidising substances, mixed with the fixed oils to quicken their drying or oxidising.

Pigments or finely powdered covering and colouring matters, mostly of some mineral substance, such as a metallic carbonate or oxide, mixed with the vehicle to give it opacity and colour.

All coloured pigments are deficient in covering power or "body," which is measurable by the extent of surface that the pigment, when mixed with oil or water, is capable of completely concealing from view. To supply this want of "body," and at the same time to produce the required tint, by far the most important pigment hitherto employed has been white-lead. It is hoped, however, that this highly poisonous material has at last found a successful rival in Griffith's White (see p. 278).

Many pigments can be used as water-colours, which would have far too little body for oil-painting. A good pigment for oil-painting should mix readily with oil, at the same time retaining its opacity, and should not "saponify" or form a soap, which occurs to a certain extent even with white-lead, tending to reduce its opacity.

Varnishes or transparent drying oils and gums, used without any colouring matter.

VEHICLES.—The ordinary vehicles used by the painter are *linseed oil* and *oil* or *spirits of turpentine,* as well as *methylated spirits* for inodorous paints.

Linseed Oil.—Linseed oil is a *fixed* or *fatty* oil obtained by crushing the seeds of the flax plant; it is the most important of all the drying oils, or oils which thicken and harden by the absorption of oxygen from the air, and consequently is invaluable to the painter and varnish maker; it dries better, and acquires greater toughness and flexibility, and consequently resists the weather better than any other of the drying oils, such as *poppy oil* or *nut oils.* This oil, by sinking into the pores of the wood and there hardening, forms a durable and impervious coat, more

especially when mixed with white-lead, with which it to some extent combines chemically to form a soap.

Raw linseed oil, or the oil in its natural state, merely allowed to settle and then drawn off clear, dries slowly and is of a transparent pale amber colour, which is apt to injure delicate tints; it can, however, be clarified by mixing an acid with it, such as oil of vitrol, after which the acid must be well washed out with water. Its colour and drying properties improve by keeping for several years, and it should not be used for at least six months after being expressed from the seeds.

Boiled linseed oil dries or absorbs oxygen much more rapidly than the raw oil, hence the liability of linen, etc., waterproofed by oiling, to spontaneous combustion, if not stored with due care. It is thicker, darker in colour, and less clear than the raw oil, but should, on account of its superior drying properties and greater body, always be used for outside work.

The "boiling" consists of heating the oil (which does not boil in the ordinary sense of the term, but when heated up sufficiently will begin to decompose and bubble up from the escape of gaseous hydrocarbons) up to about 200°, then adding a mixture of litharge and red-lead, both oxides of lead, and raising to about 400° Fahr., at which it is maintained for two or three hours, when the oil is drawn off and the albuminous matters allowed to settle, leaving the oil bright and clear, a little umber being generally added to darken the colour, as there is an absurd prejudice in favour of a dark-coloured oil.

If the body of the paint is to be zinc-white instead of white-lead, peroxide of manganese should be added as a drier to the oil instead of litharge and red-lead. Boiling the oil will improve its drying properties, without adding any drier, though not to the same extent; or the drying of the oil may be improved without boiling by adding about 1 lb. of white-lead to every gallon of oil, and allowing it to settle for at least a week; this also improves the colour of the oil, whilst the lead can be used afterwards for common work.

By an improved system of boiling by steam heat, and driving air through the oil, much time is saved. When boiled it becomes much thicker, and is not so suitable for indoor or delicate work, nor will it do for grinding up colours, as it clogs and thickens too rapidly. Good boiled oil spread in a thin film on glass, metal, porcelain, or sized paper, should become quite hard in from

twelve to twenty-four hours, whereas the raw oil would take from two to about seventeen days to dry, a good deal depending on the temperature and dryness of the atmosphere.

M. Chevreul, the French chemist, found that the drying of the oil depended upon the substance it was applied to; for instance, one coat of linseed oil applied to some oak took thirty-two days to dry, and three coats one hundred and fifty-nine days, whereas on poplar three coats dried in twenty-eight days, and on Norway fir in twenty-three days; whilst on brass, copper, zinc, iron, porcelain, and glass, all treated at the same time, one coat dried in two days. He also states that the drying properties of boiled oil might be obtained, without discoloration, by exposing it for eight hours to a heat of 158° Fahr., and then adding peroxide of manganese; or for only three hours if metallic oxides, such as litharge and red-lead, are added.

Poppy Oil.—Poppy oil is expressed from the seeds of the poppy, and though inferior in tenacity and drying properties to linseed oil, is, on account of its being nearly colourless, sometimes used for mixing with paint for ornamental internal work, when very clear colours are required.

Nut Oils.—Some nut oils are used by painters, on account of their cheapness, for common work, but their drying properties are not to be relied on, and as they are much inferior to both the linseed and poppy oils in all the qualities which tend to make a good durable coat, they should be carefully avoided except for the most temporary purposes.

Oil of Turpentine.—*Spirits* or *oil of turpentine,* commonly called *turps,* is used as a solvent for gum rosins, as well as with linseed oil to dilute paint; and also by itself, in flatting coats, as a vehicle for applying the colouring matter, when the glossy surface left by paint mixed with linseed oil is not considered desirable.

Turps is an *essential* or *volatile oil,* and one of a large class of hydrocarbons derived from the vegetable kingdom, which, when exposed to air and light, absorb oxygen, become thicker and darker in colour, losing their strong odour, and being gradually transformed into a substance resembling rosin. It is obtained by distilling turpentine—a resinous viscous body like honey, of a yellowish gray colour—which exudes from trees of the coniferæ tribe, and contains rosin, or resin, dissolved in oil of turpentine. The turpentine produced by the "Pinus canadiensis" is called

Canada balsam; by the "Pinus larex" or larch, *Venice turpentine;* by the "Pinus maritima," grown extensively in the South of France, *French turpentine;* and by the "Pinus Picea pectinata" or silver fir, *Strasburg turpentine.*

Ordinary oil of turpentine has a specific gravity of ·87, and boils at 320° Fahr.; that most generally used comes from America.

When spread upon any surface in a thin film, it should dry in twenty-four hours, leaving a hard varnish.

Turps is adulterated with mineral oils and spirits; vegetable turpentine when exposed to the air loses bulk, but gains in weight from absorption of oxygen, which is not the case with mineral oils. Its quality may also be judged from its weight and inflammability, the lightest and most inflammable being the best.

The following remarks on turpentines are taken from vol. xxv. of Knight's *Weekly Volume on British Manufactures,* p. 151.

" *Turpentine.*—From *oils* we may proceed to *turpentine,* another valuable aid to the painter. Although distilled for use in this country, yet it is primarily prepared abroad; and the source whence it is obtained so instructively shows the bountiful manner in which nature furnishes useful products, that it may be well to glance at the subject generally.

" There is a singular variety in the resinous products of the *pine* and *fir,* according to the species from which they are obtained, and the mode of obtaining them. Some result from a simple incision in the trunk of the living tree; some require a process of heat to obtain them; some are solid; some liquid. The best mode of viewing the matter will be perhaps to take in succession the species which yield the best known resinous products.

" The best *turpentine*—viz. that of Chio or Cyprus, and which gives name to all the other kinds, is not the growth of the pine or fir genus; but all the other kinds, such as Venice turpentine, Strasburg turpentine, and the common turpentine, are produced from this genus. All turpentines are produced by making incisions in the living tree, from which a kind of juice flows out.

" **Strasburg Turpentine.**—The Strasburg turpentine is a kind which is produced from the silver fir (*Pinus Picea pectinata*); and Mr. Loudon's account of the mode adopted by the Italian peasants in collecting it will well illustrate the general way of procuring turpentine.

" 'At about the month of August in every year the peasants

proceed towards the fir forests on the Alps. They carry in their hands sharp-pointed pouches called "cornets," and tin vessels suspended from girdles round the waist. Thus accoutred, they climb to the summits of the loftiest fir trees, their shoes being armed with cramping irons, like spurs, which enter into the bark of the tree, and thus support the wearer. The resinous fluid is contained in small tumours or blisters, under the epidermis of the bark; and the peasant, clinging to the trunk of the tree with his knees and one arm, presses the sharp extremity of his cornet against the little tumours. An incision being thus made, the cornet is soon filled with the clear turpentine which flows from the blister. The man then empties the treasure into the tin bottle slung to his waist, and proceeds to another tumour in a similar manner. When the bottle is full the turpentine is strained into a large leather or goat-skin bottle. This straining is to free the turpentine from the leaves, moss, and bits of bark which may have fallen into the bottle, and this is the only preparation that is given to this kind of turpentine, which is kept in the skin or leathern bottles for sale. Good Strasburg turpentine ought to be clear, free from impurities, transparent, and of the consistence of syrup, with a strong resinous smell, and rather a bitter taste. It is employed, as well as the essential oil of turpentine distilled from it, both in medicine and in the arts. The essential oil is distilled with water from the turpentine, and there is left remaining a solid residue which is black resin.'

"**Venice Turpentine.**—The *larch*, which forms a particular kind of the coniferæ, is the tree which yields the 'Venice turpentine' sold in the shops. Unlike the Strasburg turpentine, this product is obtained from incisions in the trees themselves, instead of from tumours or excrescences on the upper branches. When the sap of a vigorous larch begins to be in motion in the spring, drops of turpentine are often seen exuding from the bark; and if the trunk were split, it would in such case be found to contain several deposits of liquid resin, at 8 or 10 inches depth within the bark. It is in the mountain valleys between France and Savoy that this kind of turpentine is principally collected. The peasants of the valley of St. Martin, in the Pays de Vaud, use augers nearly an inch in diameter, with which they pierce the full-grown larches in different places, beginning at a height of 3 or 4 feet from the ground, and mounting gradually to 10 or 12 feet. They choose, generally, the south side of the tree,

and, where practicable, the knots formed by branches which have been broken or cut off, and through which the turpentine easily exudes. The holes are always made in a slanting direction, in order that the turpentine may flow out of them more readily; and care is always taken not to penetrate to the centre of the tree. To the holes thus bored are fixed gutters made of larchwood, an inch or two in width, and about half a yard long. One of the ends of each gutter terminates in a peg, through the centre of which a hole is bored, half an inch in diameter. This end of the gutter is forced into the hole made into the tree, and the other end is led into a small bucket or trough, which receives the turpentine. A very picturesque appearance is presented in a larch forest, in fine spring weather, by the vast number of little buckets at the foot of the trees, each attached to a tree by a slender tube or gutter, through which the clear limpid turpentine, glittering in the sun, trickles down into the bucket; while every morning and evening the peasants hasten from tree to tree, examining their buckets, taking away or emptying those that are full, and replacing them with empty ones. This scene continues from May to September, during which a full-grown larch will yield about 7 or 8 lbs. of turpentine, which requires no other preparation to render it fit for sale than straining it through a coarse haircloth to free it from impurities. If it happens that turpentine does not flow from a hole, the hole is stopped with a peg, and not reopened for two or three weeks; after which the turpentine is found to have collected in considerable quantity. The Venice turpentine thus obtained is clear, transparent, of the consistence of a thick syrup, with a bitter taste and a strong disagreeable smell. It is employed in making varnishes, in veterinary surgery, and in various departments of medicine.

"**Common Turpentine.**—The common turpentine, yielded by the Carolina pine, is procured in a way somewhat different from either of the above. In the month of January or February cavities are made in the trees, at a few inches from the ground: these are incisions or notches, generally of a sufficient size to hold about 3 pints of sap, but proportioned to the size of the tree. When these cavities, which in America are called 'boxes,' are made, the ground is raked, or cleared from leaves or herbage. The 'boxes' are intended to receive the turpentine or sap of the tree, which generally begins to flow about the month of March,

and becomes very abundant as the weather gets warmer. In about a fortnight the box becomes full, and a wooden shovel is used to transfer its contents to a pail, by means of which it is conveyed to a large cask placed at a convenient distance. The edges of the wound are chipped every week; and each box becomes filled in about three weeks. Long continued rains check the flow of the sap, and even cause the wounds to close; and for this reason very little turpentine is procured in cold, damp seasons. The turpentine which solidifies around the edges of the incision is sold as an inferior kind; and a mixture of the two kinds, known as Boston turpentine, is used in the soap manufacture."

Driers.—As the drying of linseed oil is due to the readiness with which it absorbs oxygen, the process is accelerated by adding substances called *driers* or *siccatives* which, in yielding up the oxygen they contain, encourage the oxidation of the oil.

As many pigments retard the drying of the oil, the addition of driers is necessary to prevent the paint from remaining sticky or "tacky," as it is termed.

The principal driers are *acetate* or *sugar of lead*, and *sulphate of zinc* (improperly called *white copperas* and *white vitrol*) either ground or in solution, for light colours; *japanner's gold size* (oil boiled on litharge) for lakes; and generally *litharge* (oxide of lead), though sometimes *verdigris* and *binoxide of manganese*, for dark colours. Less powerful driers are the *acetate of copper*, *massicot*, and *red-lead*, but much depends upon selecting a drier suitable to the particular pigments employed, as their various affinities cause them all to have more or less appropriate driers; for instance, with *zinc-white* (oxide of zinc) lead driers must be avoided, and either sulphate of zinc or of manganese must be used; the best drier for zinc-white paint is said to be about 10 per cent by weight of boiled linseed oil and peroxide of manganese, mixed in the proportion of 20 oil to 1 of manganese.

The following points should be observed in using driers:—

1*st*, not to use them unnecessarily with pigments which dry well in oil colour.

2*d*, not to employ them in excess, which would only retard the drying.

3*d*, not to add them to the colour till about to be used.

4*th*, not to use more than one drier to the same colour.

5*th*, to avoid the use of patent driers.

6*th*, to avoid the use of driers in the finishing coat of light colours, as they are liable to injure the colour.

PIGMENTS.—The pigments, or solid matters used to give body, opacity, and colour, to paint, are chiefly earths or metallic carbonates and oxides, such as carbonate of lead, oxides of lead, iron, and zinc, which have very little tendency to unite with the oxygen in the air, and can be brought to a very fine state of powder. They are sold generally in a dry powder or else ground in oil. Inferior pigments will retard the drying of the paint, and should therefore be avoided; moreover, some pigments, when in contact, act upon each other so as to retard the drying. Silica, reduced to a fine state of powder, is much used in some of the new patent paints, and forms a very permanent base.

White-lead.—White-lead is a carbonate of lead; when united with oil it has greater covering power than any other known pigment (the newly discovered oxysulphide of zinc or Griffith's White excepted); hence it has formed the basis of most the oil paints hitherto used for house painting.

The adulteration of white-lead is an acknowledged thing, the nature of such adulteration and the extent to which it is carried governing the price as well as the name applied to the mixture; it is very difficult to obtain white-lead in its pure state, unless got direct from a manufacturer, by whom it is sold in the dry state as *genuine dry white-lead* or *flake white*, in powder or else in lump; but it is chiefly sold in paste containing from 7 to 9 per cent of linseed oil, and more or less adulterated, unless specially marked *genuine*. It is by no means necessary to insist in all cases upon its purity, provided that the price paid is in proportion to the quality of the materials employed.

Sulphate of baryta (heavy spar) and whiting (powdered chalk) are commonly mixed with white-lead. When used singly they are easily detected by the weight, whiting being much lighter than white-lead, which weighs about 400 lbs. per cubic foot; whereas sulphate of baryta, though very similar in appearance, is rather heavier than white-lead; it has not the same covering properties when mixed with oil, although very useful as a water-colour pigment on account of its permanence. When sulphate of baryta is used for adulterating white-lead in combination with whiting, the weight can be adjusted so as to defy detection by any other than chemical tests.

Tests for White-lead.—The amount of sulphate of baryta in

white-lead is readily ascertained by treating it with dilute nitric acid (acid mixed with an equal amount of distilled water), which dissolves the lead and leaves the sulphate; if ground with oil the oil must be burnt off before the acid is applied, which may be done by placing it in a clean iron spoon and heating it over a clear fire until it falls to a powder; then put it in a glass or porcelain vessel, add the dilute acid, warm it, and, after the lead appears to be dissolved, add a little more of the acid until effervescence ceases; then pour off the acid, and wash any residue there may be with water; this insoluble portion will be the sulphate of baryta, or other matter used to adulterate the lead.

If the lead is to be tested for whiting, place it in a porcelain vessel, and warm it well with some strong muriatic acid, then add a large quantity of water and warm it up again, let it settle, pour off the acid and water, and add hydrosulphate of ammonia until all the lead is dissolved, let it settle, pour off the liquor, and add ammonia and oxalic acid; should a white precipitate be produced it will be whiting. The time taken in each distinct operation will depend upon the amount of impurity in the lead.

White-lead should be old; if too fresh the white paint made with it is apt to acquire a yellowish tinge, but it must not be kept exposed to the air, otherwise it will turn to a dark gray.

To test for whiteness place similar quantities of a pure white pigment and the specimen to be tested side by side on a piece of blue note or foolscap paper; fold the paper over them, gently pressing it down till the edges of the two specimens touch; on opening the paper any difference of tint will be plainly visible.

Krems White.—*Krems* or *Vienna white*, from Krems in *Austria*, as also *French, Roman, London, Nottingham* and *Newcastle white*, are names given to pure white-leads prepared in different ways.

Venice White.—*Venice white* is the name given to white-lead and sulphate of baryta in equal proportions.

Hamburg White.—*Hamburg white* is 1 white-lead to 2 sulphate of baryta.

Dutch White.—*Dutch* or *Holland white* is 1 white-lead to 3 sulphate of baryta.

Zinc-white.—*Zinc-white*, which is an oxide of zinc, does not combine with the oil or *cover* so well as white-lead, nor is it so capable of resisting the carbonic acid contained in rain-water, and therefore does not weather so well; but as white-lead, in addition to being highly poisonous, is rapidly discoloured by noxious gases.

sulphuretted hydrogen for instance, zinc-white has of late years been used for such purposes as painting chemical laboratories; it is preferable to white-lead in putting a white coat over a dark ground, as the saponification of the lead with the oil forms a semi-transparent soap, which in time allows the dark ground to strike through.

Zinc-white paint, when pure, retains its colour well, and will stand washing for several years without losing any of its freshness. The purest zinc-whites are wanting in density or body, hence those supplied by the Vieille Montagne Company are preferable to those which come from America.

It is very slow in drying, and requires to be treated with special driers, as already mentioned, in addition to which it requires more working with the brush than white-lead, and therefore is not liked by painters. When dry it becomes very hard and will take a fine polish. Being in every way inferior to the oxysulphide of zinc or Griffith's White, it is now entirely superseded by the latter, and will soon cease to be made.

Griffith's White.—This is an oxysulphide of zinc manufactured from sulphate of zinc and sulphide of barium, the principal British makers being Griffith, Berdoe, and Co. It is non-poisonous, and is said to be more economical than white-lead and superior to it in covering power, colour, durability, and permanence of colour and opacity. It is unaffected by noxious gases, which discolour white-lead and gradually destroy zinc-white, or by extremes of temperature, and it does not blister. It mixes well with oil or water, without injuring the most delicate tints, and works freely under the brush. If only the test of time supports its claims, it ought to put an end forever to the use of white-lead, with its many attendant evils.

Red-lead.—*Red-lead,* or *minium,* is a plumbate of binoxide of lead, and is only durable when used pure, and not exposed to any acids or foul air. Any preparation of white-lead, oxides of lead or metallic salts, will discolour it, and reduce it to a metallic state. It dries in oil, and is therefore frequently used as a gentle drier; but the protoxides of lead—namely, massicot and litharge, especially the latter, dry more rapidly than the binoxides. It is used with white-lead and oil as a priming for wood, and with oil only for the two first coats

on ironwork, as it has less action upon iron than paints containing white-lead. Red-lead is often adulterated with brickdust, and a sesquioxide of iron called colcothar or English rouge, which is itself often adulterated with sulphate of baryta.

A sulphide of antimony, known as antimony vermilion, has lately been used in place of red-lead. It is obtained in a very fine powder, and when ground in oil gives a brilliant red with a good body. It is unaffected by light, foul air, or acids, has no taste or smell, and is insoluble in water, alcohol, or essential oils.

Colouring Pigments.—As a general rule those colouring pigments which are simply natural earths, or the sooty or calcined products of animal or vegetable substances, subjected to no other treatment than grinding, and in some cases heat, are durable, and neither injurious to the health nor to other pigments.

The principal colouring pigments in use, including whites and blacks, are given below, arranged according to their durability, etc.

Instead of using the simple pigments given for the secondary colours, they can, of course, be obtained by mixing two primary colours, thus, yellow + red = orange; yellow + blue = green; red + blue = purple. Also by different mixtures of the three primaries, the tertiary colours are obtained; as *citrine* in which yellow, *russet* in which red, and *olive* in which blue predominates.

For fuller details and the more delicate pigments, see *Painting* (Virtue and Co.'s Series).

Table of the best and most permanent pigments, little, if at all, affected by light, shade, damp, gases, lead, or iron. They do not affect other pigments, and are not injurious to the health.

The letters against the colours signify as follows :—

a = More or less transparent, and therefore fit for graining and finishing.
b = Little, if at all, affected by heat or fire.
c = Little, if at all, affected by lime, and therefore suitable for fresco and distemper painting.

Colours.		Composition.
Whites.		
Griffith's white . .	*b*	Oxysulphide of zinc.
Zinc white . . .	*b*	Oxide of zinc.
Constant or barytic white	*bc*	Sulphate of baryta.
Tin white . . .	*b*	,, of tin.
Pure earth whites . .	*bc*	Lime carbonates or sulphates.

Colours.		Composition.
Yellows.		
Cadmium yellow . .	*ab*	Sulphide of Cadmium.
Yellow ochre . . .	*c*	Fine clay naturally coloured with oxides of iron and manganese.
Spruce or brown ochre .	*c*	,, ,,
Roman ochre . . .	*c*	,, ,,
Oxford ,, . . .	*c*	,, ,,
Stone ,, . . .	*c*	,, ,,
Raw Sienna ochre . .	*ac*	,, ,,
Reds.		
Vermilion . . .	*c*	Tersulphide of mercury.
Antimony vermilion .	*c*	A sulphide of antimony.
Rubiates or madder lakes	*c*	Vegetable colours.
Madder carmines . .	*c*	,,
Red ochre or Spanish brown	*bc*	Natural coloured clay.
Light red . . .	*bc*	,, ,,
Venetian red . . .	*bc*	,, ,,
Indian red . . .	*bc*	Hæmatite ore, or calcined sulphate of iron.
Blues.		
Blue ochre . .		Natural coloured clay.
French ultramarine (Guimets) . . .	*ac*	Kaolin, carb. of soda, sulphur, and charcoal.
German do. (Gahnis) .		Kaolin and cobalt oxide.
Oranges.		
Orange or Spanish ochre .	*bc*	Natural coloured clay.
Mars orange . . .	*abc*	,, ,,
Burnt Roman ochre .	*bc*	,, ,,
Light and Venetian red .	*c*	,, ,,
Burnt Sienna . . .	*abc*	,, ,,
Greens.		
Pure chrome or native greens	*abc*	Oxide of chromium.
Terre-verte . . .	*ac*	Natural coloured clay.
Cobalt green or Rinman's green . . .	*bc*	Cobalt and ferrous oxide of zinc.
Purples.		
Madder purple . .	*ac*	Vegetable colour.
Purple ochre . . .	*bc*	Natural coloured clay.
Russets.		
Madder brown or russet rubiates	*a*	Vegetable colours.

Colours.		Compositions.
Browns or Semi-neutrals.		
Bistre	*ac*	Wood or peat soot.
Vandyke brown . .	*ac*	Bituminous earth.
Browns or Semi-neutrals.		
Turkey umber, raw .	*ac*	Bituminous earth.
Com. English, ,, . .	*ac*	,, ,,
Burnt umber . . .	*abc*	,, ,,
Cologne earth . .	*abc*	,, ,,
Cassel earth . . .	*bc*	,, ,,
Asphaltum . . .	*ac*	Native bitumen.
Mummy or Egyptian brown	*ac*	Bituminous animal remains
Spanish brown or red ochre	*bc*	Natural coloured clay.
Sepia	*a*	From cuttle-fish.
Manganese brown . .	*bc*	Oxide of manganese.
Light cappagh brown or euchrome	*ac*	Bog earth and manganese.
Deep cappagh or mineral brown	*c*	,, ,,
Blacks or Neutrals.		
Ivory black . . .	*ac*	Charred ivory.
Bone black . . .	*ac*	,, bone.
Frankfort black . .	*ac*	Charred wood, etc.
Blue-black . . .	*ac*	Impure oxide of carbon.
Lamp-black . . .	*ac*	Smoke black.
Vegetable black . .	*ac*	,,
Indian ink . . .	*c*	,,
Mineral black . .	*bc*	Impure native oxide of carbon.

The following pigments are little, if at all, affected by light or pure air, but are more or less injured by shade, damp, and impure air, especially if containing sulphuretted hydrogen. They are unfit for use as water-colours in distemper, though some last well when protected by oil or varnish. Most of them darken in time.

White-leads, both pure and adulterated.

Yellows.—*Massicot* a pale yellow protoxide of lead. Injured by lead colours; resembles litharge as a powerful drier.

Chrome Yellows.—Pure, brilliant, chromates of lead, zinc, strontium, or calcium. Destructive to Prussian and Antwerp blues, when mixed for greens.

Lemon Chrome and *Mineral Yellow.*—Paler varieties of the last.

Patent Yellow, Turner's, Cassel, Verona, and Montpellier

Yellow.—Oxychlorides of lead of more or less brilliancy and durability.

Naples or *Antimony Yellow.*—A light yellow oxide of lead and antimony. Both iron and lead injure it; a steel palette knife should not be used to it.

King's Yellow.—A sulphide of arsenic.

Reds.—*Red Lead,* see page 278.

Chinese and *Persian Reds.*—Bright red chromates of lead.

Blues.—*Smalt* and other *Cobalt Blues,* such as Dumont's, Saxon, Hungary, Thewards, and Royal blue.

Oranges.—*Orange Lead,* an oxide of lead, injured by lead colours.

Chrome Orange and *Laque Mineral.*—Bright orange chromates of lead.

Chromate of Mercury.—A bright orange oxide of iron.

Greens.—*Brunswick Greens,* a large class of bright oxychloride of copper greens, made up of chrome yellow, Prussian or other blues, and sulphate of baryta.

Mineral Greens or *Green Lakes.*—Sulphates of copper of various shades, in very common use.

Acetate and *Arsenite of Copper Greens,* such as emerald, Scheele's, Schweinfurt's, Vienna green, and verdigris, being highly poisonous, are to be avoided; more especially as water-colours for distemper.

In addition to the blues given above, Prussian and lighter and brighter blues, called Antwerp and Haarlem blues, are much used, though very expensive, fading in strong lights and darkening in damp and impure air. Indigo or Indian blue is both powerful and transparent, though inferior in every way to Prussian blue. Blue verditer, Saunder's blue, and mountain blues are copper blues, not durable, and becoming green when used in oils.

VARNISHES.—*Varnishes* are used either without paint to preserve the material they are applied to, to give a hard shiny surface, and make the natural grain or any design *bear out* well; or as a transparent finishing coat to paint, to add to its appearance and durability. For some purposes, such as over woodwork, where expense is an object, a coating of linseed oil, with or without wax, is quite sufficient, but a better appearance is obtained by using *varnishes,* which are solutions of *resins* or *gums*—gums are soluble in water, whilst resins will only dissolve in spirits or oil,—and may be classed, according to the solvent used to act the part of

a vehicle, as *water varnishes, spirit varnishes* or *lacquers, essential oil varnishes,* and *oil varnishes,* the latter only being suitable for outdoor work; but in practice they are mostly distinguished by the substance from which they are prepared, as *copal varnish, mastic varnish, lac varnishes, cowdie varnish,* and *crystal varnish,* made from Canada balsam.

The resins used for making varnish are the solid residue obtained from turpentines, after driving off the essential oil by distillation; if the distillation of turpentine be continued to dryness, the residue is *black resin;* but if water is stirred about in the turpentine, while still fluid, the solid residue is what is known as *yellow resin.*

The following is an extract from the lectures on "Building Materials" delivered at the S. M. E., Chatham, in 1871, by Mr. W. Y. Dent.

"Varnish should be examined from five different points of view, viz.:—Quickness of drying—hardness of coating produced—the amount of gloss possessed by such coating—the permanence of the gloss—the durability on exposure to the weather. It should be borne in mind that, with varnish of the same consistency, very quick drying and durability are not compatible; the addition of a large quantity of litharge, sugar of lead, or white copperas (which are the driers used) being to some extent detrimental to the permanence of the varnish. Good varnish should, however, dry hard in the course of one or two days, so as not to be adhesive when touched, unless the weather be very unfavourable. The greater the proportion of oil, the less liable the varnish is to crack."

It is essential to good varnishing that it should be done in fine weather, and that it should not be exposed while drying to currents of cold or damp air; moreover, age is needed for all varnishes. One pint of varnish will cover about 16 yards super for a single coat.

Copal Varnish.—Copal varnish is the best, and is prepared from copal dissolved under heat with the best linseed oil. No other varnish should be used for outside work.

The following receipt for *white copal varnish* is given in Tomlinson's *Encyclopædia of Arts:*—Mix 4 ounces of powdered copal with ½ ounce of camphor and 3 ounces of the best raw linseed oil, heat them over a slow fire, then add 2 ounces of oil of turpentine, and strain.

Common Varnish.—Common varnish is made by dissolving 2 lbs. of resin, under a gentle heat, in 1 gallon of linseed oil, and then adding gradually 1 quart of turpentine.

Mastic Varnish.—*Mastic varnish* can be made by heating $\frac{1}{4}$ lb. of mastic over a slow fire with one pint of oil of turpentine, and straining.

Special Paints.—Several descriptions of paint—the use of which is gaining ground every day—have of late years been introduced to meet the objections to the ordinary oil and lead paints, such as their unpleasant odour, poisonous nature, chemical action on metals, liability to chemical change under the influence of acids, etc.

The following extracts on inodorous paint, indestructible paint, and anti-corrosive paint, are taken from the lectures by Mr. W. Y. Dent referred to above:—

"**Inodorous Paint.**—The unpleasant odour which arises from fresh paint is due to the evaporation of the turpentine, and not being a very volatile liquid, this odour, which affects persons very differently—sometimes producing nausea and headache, besides other more serious symptoms of illness,—lasts for two or three days, to the great inconvenience of those subjected to its influence. To obviate these unpleasant effects arising from the use of turpentine, which are the necessary results of painting in the ordinary manner, it has recently been proposed to do away with the use of turpentine altogether, by adopting a process which has been patented by Mr. Cox, under the name of inodorous paint. In preparing paint to be used in this manner, ordinary white-lead or white-zinc ground in oil in the usual manner, instead of being thinned with boiled oil and turpentine, is mixed with methylated spirit in which shellac has been dissolved, together with a small quantity of linseed and castor oil. Methylated spirit is spirit of wine to which 10 per cent of wood spirit is added, according to excise regulations, in order to render it unfit for drinking, so as to enable spirit of wine to be used for manufacturing purposes without paying the duty imposed on pure spirit, the price of which is enhanced about five times by the duty; for whilst a gallon of pure spirit costs about 20s., the price of the methylated spirit is only about 4s. This methylated spirit evaporates very rapidly, leaving behind the shellac, which acts the part of the film of varnish left by the oil and turpentine in the ordinary method of painting, protecting the wood or stone, and at the same time attaching the pigment to the painted surface. The first coat of paint applied in this manner is capable of being followed by a

second in the course of an hour, and three-coat work is thus capable of being completed in the course of a single day.

"In oak graining it is desirable, perhaps better, that the varnishing coat should be put on as usual; but in this case the odour arising from two coats of paintwork is at all events avoided, and the whole is finished in a day, instead of lasting over two or three days. The actual amount of pigment which covers the surface is as great, if not greater, than in ordinary paintwork, since the paint is put on of the usual consistency, the thin character of the spirit, as compared with oil and turpentine, being compensated to great extent by the shellac, but partly by the greater quantity of pigment. For interior work there can be no doubt but that this method of painting is a great advantage, more especially in cases where it is necessary that paintwork should be done in dwellings in which invalids are residing. It is not at all unlikely that it may also be found adapted for exterior work, but I have not had an opportunity of judging of this paint sufficiently to express any decided opinion. This paint dries so rapidly that there is a little difficulty in painting a large flat surface without it sometimes showing marks where one portion has been completed and another commenced; but wherever there is any break in the work, such as is produced by panels, this defect is not observable.

"There are two kinds of solution prepared, the difference chiefly consisting in the use of bleached shellac for the more expensive kind, which of course dries of a whiter colour than that made with ordinary shellac.

"**Indestructible Paint.**—The paints employed by the Indestructible Paint Company have recently acquired some notoriety. They consist of two kinds. The light coloured or enamelled paints are composed of a metallic oxide, such as oxide of zinc or oxide of lead, ground with a small quantity of oil, and mixed with petroleum spirit holding resinous matter in solution, while for the darker paints a mixture of petroleum spirit and bitumen is used.

"**Anti-corrosion Paint.**—The paint known by the name of *Anti-corrosion* consists of a mixture of ground-glass and white-lead in equal proportions. It is sold in a dry state, and only requires to be mixed or stirred with oil to form a paint, without necessitating the use of mixing or grinding rollers, as is the case with ordinary white-lead or zinc-white. It is considered to be particularly adapted for exterior work, lasting longer than white-

lead alone, and costing less. The original makers of this paint are Messrs. Walter Carson and Sons; and if genuine, as supplied by this firm, it should consist of ground-glass and white-lead in about equal proportions. The rubbish which is frequently sold as anti-corrosion has greatly injured the reputation which this paint at one time possessed. It can be obtained as low as 6s. per cwt., whilst the price of the genuine is from 22s. to 24s. It is not at all uncommon to find anti-corrosion containing from 35 to 45 per cent of sulphate of baryta, a substance which, I am assured, is never employed by the original makers."

An anti-corrosive paint is also made of equal proportions of whiting and white-lead, with half the quantity of fine sand or road dust, and any required colouring matter. Being mixed with water it can be used as a water-colour, but is generally applied as an oil paint, the best oil for the purpose being 1 boiled to 12 of raw linseed, and 3 of sulphate of lime, all by weight. One gallon of the oil will take 7 lbs. of the paint.

Silicate Paints.—The silicate paints supplied by the Sanitary Paint Company are highly recommended by the architect to the London School Board for all internal work where health and cleanliness are aimed at; especially in passages, halls, kitchens, schools, and hospitals; he says, "I find that after the expiration of two or three years they become like new on the application of soap and water and the scrubbing brush."

Petrifying Silicates.—The *petrifying liquid* supplied by the Sanitary Paint Company is used as a damp-proof coating for external walls. It is said to render any porous substance impervious to damp by filling up the pores with a hardening solution, of which silica forms the enduring base. It may also be used for coating new plaster or damp internal walls, in order to allow of their being papered without delay; also to give a non-absorbent surface to hospital and cell walls, etc., as well as instead of paint, especially over iron, where exposed to the weather.

A similar composition to the above, called Silicate Zopissa, is manufactured by the Granitic Paint Company. It can be had either white, brick red, stone colour, or transparent; but can be made to order of any colour, in quantities not less than 2 cwts.

Granitic Paint.—The Granitic Paint Company also manufacture a paint which, whilst it does not affect metallic substances, is said to be more durable and cheaper than, and unaffected by any of the agents which tend to destroy, the ordinary lead paints.

It is used both for internal and external painting, whether rough or highly decorative. It is said not to blister, and to be proof against heat, moisture, frost, sea air, or water; and also to be better than red-lead for joints in ironwork; it does better for rough than for planed woodwork, whilst one coat on iron or stone gives as good an appearance as two coats of most ordinary paints. Its durability when exposed to sea air has been tested with very satisfactory results.

One lb. of the light colours will cover 6 yards with two coats on stone or cement, or one coat on wood, and much more in the dark colours. Both priming and different colours are sold, either ground in oil or in a powder, ready for mixing with oil and turps in the usual way.

Oxide of Iron Paints.—These paints are free from all deleterious matters; they are cheaper, since they go further than lead paints, and, when mixed with about one-third of white-lead, form a very hard mastic similar to that made from red-lead. They are supposed to have more affinity for iron than lead paints, forming a better protection against the air, especially where rust is present, when it is claimed that by working the paint on well with a hard brush the oxide on the iron amalgamates with the oxide in the paint, and the decay is arrested. The principal kinds are:—

Wolston's Torbay paint, a protoxide of iron, manufactured from a brown hæmatite iron-ore, contains about 64 per cent of oxide of iron and 33 per cent of silica. When pure it should not contain any sulphate of baryta. It ranges from a yellowish brown to black, but is mostly of a rich brown colour. For other colours, such as for lead colour, red, invisible green, chocolate, bronze-green, stone, and drab, special pigments must be added. One coat of Oriental red (No. 18, Wolston's Torbay paint list) finished with two coats of lead paint to the required colour makes very good work. For the last twenty years it has been extensively used for ships, workshops, machinery, boilers, etc.; and is well adapted (especially on iron) for resisting the weather, as well as the vapours and fumes in large manufactories; though it does not resist sea air so well as granitic paint. It is cheaper than the lead paints, since weight for weight it goes much further.

The Cambrian Chemical Paint Company's paints claim to be pure oxides of iron; 1 lb. covering, it is said, 8 yds., 1 coat on iron, equal to 2 or 3 of ordinary paint, and much more durable.

Black oxide of iron paint is largely used for shot and shell. The finely-powdered black oxide of iron, obtained in manufacturing aniline dyes, is ground in oil with about 15 per cent of terra

alba, Paris white, or sulphate of baryta, to counteract the tendency of the oxide to set in a hard mass, when ground alone in oil.

Grant's black, made from a shale containing oxide of iron, and sometimes as much as 60 per cent of silicious matter.

Purple-brown oxide is a hydrated peroxide of iron.

The *oxide silicate paints,* such as are manufactured by the Silicate Oxide Paint Company of Ashburton, Devon, and by Messrs. O'Hara, Wilcox, and Co., of Westferry Road, London, contain oxide of iron and silica in nearly equal proportions, and have the advantage of not requiring turps, which is said to prevent their drying. They are cheaper than, weight for weight, and quite equal to, the Wolston and other Torbay paints. One pound of these paints will cover from 2 to 3½ yards one coat on wood, and about twice as much on iron. The powder mixed with tar is well suited for ironwork where simple coal-tar is objected to.

Brunswick Black.—*Brunswick black* as applied to iron accoutrement shelves, locks, etc., said to be japanned, is made of ½ lb. of genuine crushed asphaltum, with 1 to 2 quarts of turpentine.

Brockley Black, etc.—*Brockley black* for boilers, engines, etc.; *antifouling paint* for wooden and iron ships; funnel paint prepared not to blister or scale with heat; anticrustation fluid for removing and preventing incrustation in boilers; are all special paints manufactured by the Sanitary Paint Company.

Griffith's Enamel Paint.—*Griffith's enamel paint,* supplied by the Sanitary Paint Company, is non-poisonous, and is said to be proof against hot and cold water, sea air and water, gases, and even dilute acids. It is sold in all colours, ready for use. It dries rapidly, with a glossy surface like porcelain, is hard, durable, and bears constant washing with soap and water. It is applicable to wood, iron, or any substance. One coat is said to be sufficient for waterproofing, being equal to an ordinary coat of lead paint varnished, and wet only hardens the enamel. It can be supplied to give a flat or dead surface, which is said to be superior to, and more durable than, ordinary flatted paint.

White Enamel Paint can be manufactured as follows:—Take 5 lbs. oxide of zinc paint and add sufficient turps to convert it into a thick paste, the quantity of turps depending on the condition of the zinc; about 1 to 1½ pints to the cwt. being sufficient. When thoroughly broken up add 1 gallon of white French oil enamel varnish, a small dash of blue to improve the colour, and strain. This is only for indoor work; for outdoor work

boiled linseed oil in place of turps and copal body varnish in place of white French oil varnish.

Wood's Compo Paints.—These are coloured varnishes rather than paints, and very good for temporary outdoor work, containing neither oil, turps, nor driers, and drying rapidly with a bright gloss. They neither crack nor blister in the sun, and one coat on bare iron, stone, or wood, is equal in appearance to two of ordinary paints, but they are not so durable as the best oxide of iron paints. They are obtained ready for use from the Talbot Works, Hatcham, Surrey.

Fireproof Washes and Paints.—A solution of *silicate of soda*, invented by Sir F. Abel, C.B., F.R.S., Chemist to the War Department, applied to wood, as directed below, gives it a very considerable protection against fire, and forms a hard coating, durable for several years; it can be used with the ordinary colours like distemper.

"*Materials employed.*—The silicate of soda must be in the form of a thick syrup of a known degree of concentration, and is diluted with water for use as directed below.[1]

"The lime-wash should be made by slaking some good fat lime, rubbing it down with water until perfectly smooth, or with equal parts of whiting and zinc-white ground together dry, and diluting it to the consistency of thick cream. It may be coloured by admixture with mineral blacks, ochres, etc.

"*Treatment of the wood.*—The protective coating is produced by painting the wood: firstly, with a dilute solution of silicate of soda; secondly, with a lime-wash; and lastly, with a somewhat stronger solution of the silicate.

"The surface of the wood should be moderately smooth, and any covering of paper, paint, or other material, should be first removed entirely by planing or scraping.

"A solution of the silicate, in the proportion of 1 part by measure of the syrup to 4 parts of water, is prepared in a tub, pail, or earthen vessel, by stirring the measured proportion of the silicate, first with a very small quantity of the necessary water, until a complete mixture is produced, and then adding the remainder of the water, in successive quantities, until a perfect mixture in the requisite proportions is obtained.

"The wood is then washed over with this liquid by means of an ordinary white-wash brush, the latter being passed two or three times over the surface, so that the wood may absorb as much of the solution as possible. When this first coating is nearly dry, the wood is painted with the lime-wash in the usual manner.

"A solution of the silicate, in the proportion of 1 part by measure of the syrup to 2 parts of water, is then made as above described; and a sufficient time having been allowed to elapse for the wood to become moderately dry, this liquid is applied upon the lime in the manner directed for the first coating. The preparation of the wood is then complete. If the lime coating has been applied rather too thickly, the surface of the wood may be found, when quite dry, after the third coating, to give off a little lime when rubbed with the hand. In that case it should be once more coated over with a solution of silicate of the first-named strength."

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[1] The silicate of soda syrup of proper strength, is supplied wholesale by Messrs. Gossage, Widness Dock, Warrington, and other manufacturers.

Tungstate of soda, when applied as a wash sufficiently to saturate the pores of the wood, also forms a good protection against fire.

Asbestos fireproof paint, manufactured at Bell's Asbestos Works, Southwark, resists the weather somewhat better than the silicate of soda wash, though it cannot long resist rain, and is liable to crack and flake off when exposed either to the weather or to prolonged heat; otherwise it protects any surface covered with it from ignition. Gray or stone is the ordinary colour, reds, chocolates, blues, etc., are more expensive.

Kieselghur fireproof paint, introduced by Sir Seymour Blane, is said to promise well. Its characteristics are somewhat similar to the Asbestos paint, but it has not yet been sufficiently put to the test of practice to permit of any definite decision being arrived at.

Cyanite is a colourless fireproof liquid, manufactured by the Fireproof Cyanite Company, Homerton, London. It has been much used in theatres for fireproofing the woodwork and scenery. It can be used instead of ordinary priming for woodwork, without interfering with the processes of staining, painting, and graining. A gallon, costing 9s. 6d., will cover from 1000 to 2000 yards super, according to the material.

Tar Paint for Ironwork.—For rough ironwork, much decayed, two coats of common coal-tar, with or without sand or lime, well worked on with a hard brush, is a most durable covering.

A good paint for ordinary ironwork is 1 gallon of coal-tar, $\frac{1}{2}$ a gallon of turps, and $\frac{1}{2}$ a pint of boiled linseed oil; or, according to Mr. Edwin Clark, C.E., 9 gallons of coal-tar, 2 to 3 quarts of turps, and 13 lbs of slaked lime.

But the best mixture and much used for bridge work is $\frac{1}{2}$ lb. of sulphate of lime to 1 gallon of coal-tar, with sufficient naphtha to make it work freely.

Tar and Pitch.—*Pitch, Stockholm tar,* and *coal-tar* are extensively used for coating fencing, and even walls, to keep out damp. Pitch and Stockholm tar are the resinous products obtained by the slow combustion of woods such as the firs and pines. Wood-tar being imported chiefly from Sweden and Russia came to be called Stockholm tar in order to distinguish it from coal-tar, which is cheaper than wood-tar, and is obtained by the distillation of coal in gas making.

Stockholm tar, being thinner than coal-tar, enters the pores of the wood more freely and so preserves it better.

Pitch is added to both Stockholm and coal-tar, in the proportion of from 1 to 2 lbs. to a gallon of tar, in order to fix it, and prevent its running in hot weather; a little lime is often added for the same purpose. Another mixture consists of 1 lb. of resin and 1 lb. of pitch to 6 gallons of coal-tar.

Tar should be applied hot, and Stockholm tar may be coloured with Venetian red or French yellow.

One gallon of tar mixed with 1 lb. of pitch will cover about 12 yards super for a first coat, and about 17 yards for any coat after the first coat.

The following extract is from Knight's *British Manufactures*, vol. xxv., already referred to:—

"Besides the resinous products obtained from the living tree, there are others of a peculiar kind obtained from it after it is cut down. These are *tar*, *pitch*, and *lamp-black*. All the tar of the southern states of America is made from the dead wood of the Carolina pine, consisting of the trees which have fallen from natural decay, or from hurricanes, or fires, of the summits of those which are felled for timber, and of limbs broken off by the ice that sometimes overloads the trees. When a pine tree is dead, the sapwood decays, but the heartwood becomes surcharged with resinous juice, which is productive of tar at any period for many years after the vitality of the tree has ceased.

"The mode of preparing tar from this tree in America is as follows:—A kiln is formed in a part of the forest abounding in dead wood. The wood is collected, stripped of the sapwood, and cut into billets 2 or 3 feet in length and about 3 inches thick, a task which is rendered tedious and difficult by the numerous knots with which the wood abounds. The next step is to prepare a place for piling the billets, and for this purpose a circular mound is raised, slightly declining from the circumference to the centre, and surrounded by a shallow ditch. The diameter of the pile is proportioned to the quantity of wood which it is to receive, and in the middle is a hole, with a conduit leading to the ditch, in which is formed a receptacle for the tar as it flows out. Upon the surface of the mound, after it has been beaten hard and coated with the clay, the wood is laid radially round in a circle. The pile, when finished, may be compared to a truncated cone, 10 or 12 feet high, and from 20 to 30 feet in diameter. The pile is strewed over with pine leaves, covered with earth, and held together at the sides by a slight band. A

fire is then kindled, not at the bottom of the pile, for the whole mass would soon be rapidly ignited, and the tar would be consumed instead of distilled, but at the top, whence the fire penetrates slowly downwards towards the bottom with a slow and gradual combustion. It is to retard the rapidity of combustion that the covering of earth is laid on the pile. As the wood consumes the tar flows from it, and by the end of eight or nine days a hundred barrels of tar may have flowed into the ditch, from which it is emptied into pine casks containing 30 gallons each.

"In Scotland tar is sometimes extracted from the roots of the Scotch pine, in a rude manner, for local purposes. The country people having hewn the wood into billets, put them into a pit dug in the earth. When the billets are ignited, a black thick matter runs from them, which falls to the bottom of the pit and constitutes tar. The top of the pit is covered with tiles to keep in the heat, and there is at the bottom a trough out of which the tar runs like oil.

"It is, however, from Sweden and Russia that the main supply of tar is obtained; the species of pine which yields tar in the greatest abundance being there plentiful.

"*Pitch* bears nearly the same relation to tar that resin does to turpentine; it is the solid residue obtained by evaporating or distilling tar, and is obtained in various ways, according to the nature of the pine or fir whence it is procured."

The creosote used for preserving timber is distilled from coal-tar, 100 parts of which should yield 65 pitch, 20 essential oil of creosote, 10 naphtha, and 5 ammonia; the latter dries up and destroys the wood, and must therefore be got rid of, or the process fails; a sample should always be tested to insure the absence of ammonia. Each cubic foot of timber should absorb 7 lbs. of oil; this should be tested by desiccating the timber, and weighing it both before and after the process.

Putty.—Putty is used by the painter for *stopping* or filling up holes in woodwork, about 1 lb. being required for every 20 superficial yards; it should be made of perfectly dry whiting well kneaded up with raw linseed oil, and for stopping should have some white-lead mixed with it to give it a greater hardness. For stopping coloured woods to be polished or varnished, it is coloured with red-lead or any suitable colouring matter. Holes in plaster to be painted are made good with a stopping composed of gauged stuff

or about equal proportion of plasterer's putty (p. 237) and plaster of Paris.

Pumice Stone, etc.—Pumice stone, both in lump and powdered, and sand or glass paper are used for rubbing down work to get a perfectly smooth face to paint on.

Execution of Painter's Work.

Preparing and applying Paint.—In preparing oil-paint the pigment is first rubbed up or ground with raw oil under the muller on the grindstone, or in a mill when made in large quantities, and is then diluted with oil and turps, called in the trade *thinnings,* to the consistency of cream, the driers only being added just before using. The required colour, prepared with a small amount of oil, and the thinnings are generally kept separate to allow of their being mixed on the spot in convenient quantities, more thinnings being added as the colour gets too thick to cover properly.

In laying on the paint the brush must be held at right angles to the face of the work, so that only the ends of the hairs touch it in order to force the paint into the pores of the material, and spread it evenly over the surface, without leaving streaky marks.

When a good smooth surface is required each coat should be well rubbed down with sand or glass paper, or pumice - stone, besides being well dusted, before applying the next coat.

All surfaces to be painted should be perfectly clean and free from grease, and all woodwork should be dry and well seasoned, otherwise the moisture confined in the pores of the wood will lead to dry rot setting in.

The brushes and all the utensils should be kept quite clean, being freed from all dry paint by scraping with a knife and washing with strong soda and water, otherwise the colours will soon become foul, and the work very inferior. The brushes, after use, are kept from drying hard by immersing them in water.

The paint should be strained free from skins and all extraneous matters; and if, after mixing, it has to be laid on one side for a time, in an open vessel, it should be covered with water to preserve it from the drying or oxidising influence of the atmosphere.

With ordinary paints new wood or iron work, to last properly, requires four coats, including the priming but exclusive of any flatting coat.

Killing Knots.—The first operation in painting resinous woods, such as fir, is *killing the knots,* or treating them so as to prevent the resin or turpentine from exuding and ruining the paint. This may be done by painting them over with hot lime, and when dry by ironing them with a hot iron, and then pumice-stoning them smooth; or leaving the lime on for twenty-four hours, scraping it off, and then painting them with red and white lead and linseed oil, and, when dry, pumice-stoning them smooth; but these processes take time, to obviate which a liquid called *patent knotting,* chiefly shellac and naphtha, is generally used; it forms a skin over the knots, and, by drying in about five minutes, allows of the painting going on at once.

Red lead knotting—made by grinding red lead in water and mixing with strong glue size, and used hot—is, however, considered preferable to patent knotting, and dries in about ten minutes.

When knots show through the third coat, or second coat after priming, they must be carefully covered with gold or silver leaf gummed on with size.

Priming.—The first coat of paint is called the *priming coat;* this, in ordinary lead painting on woodwork, is composed of white and a little red lead, mixed with raw linseed oil, and a little litharge ground very fine in turpentine, as a drier; the object being to fill the pores of the wood with oil before applying the colouring coats, which would otherwise be sucked up and wasted; and, on this account *raw* linseed oil—sometimes thinned with turps, even to the extent of half turps and half oil—is used; it is thinner than boiled oil, and therefore sinks more readily into the wood, the white-lead assisting this action, whilst the red lead hardens and prepares the surface for receiving the subsequent coats. For details of materials used see p. 302.

Painters will sometimes, for cheapness, prime with clearcole or glue size instead of oil, which forms a skin over the surface, without entering into the pores of the wood; it is therefore liable to peel off, and should never be allowed for outside work, and only in inside work when the surface is too greasy or dirty to take oil priming.

Stopping.—After priming comes the stopping or filling up all nail holes, etc., with putty (see p. 292), which, if applied before the priming, would become loose from the wood drawing the oil out of the putty, and causing it to shrink.

Colouring.—After all defects have been made good, and the

work has been rubbed smooth with sand or glass paper or pumice-stone, the colouring coats are applied,—the second coat, or first after priming, being diluted, for inside work, with about one-third turps to two-thirds oil, the third coat having the oil and turps in equal proportions, and the fourth coat from one-fourth to one-half oil, according to circumstances, and the degree of gloss admissible on the finished surface; the oil in these coats is boiled oil for all outside work, and raw for inside work, as the latter costs less, being thinner goes further, and having less colour is better for light tints.

For outside work less turps should be used in the second coat, and none in the third and fourth coats, in order to avoid blistering and sun cracks.

If not to be painted white, the second coat should approximate to the required colour; colouring pigments being added in the proportion of from 1 to 2 oz. to every 10 lbs. of the white pigment.

Flatting.—When, as in superior work, it is desirable to avoid altogether the glossy surface of oil-paint, a fifth coat—for which all turps and no oil is used—is added; this is called a *flatting* coat, and should be laid on before the last coat has become hard. It will not admit of washing, as oil-paint will, and therefore is not suitable for out door-work. The *ground*, or coat which receives the flatting, should be mixed with more oil than for a finishing coat of oil-paint, as the more shine is given to the ground the more dead will the flatting coat be, and *vice versâ*, the deader the ground the more will a finishing coat of oil shine up.

Sometimes a little size, or raw oil well bleached, is added to the turps, in order to enable the paint to stand washing better, in which case it is called *bastard flatting*.

Painting and Varnishing.—Varnish adds greatly to both the appearance and durability of paint, but at the same time shows up the defects of broken or uneven surfaces.

A priming coat, followed by a dark coat, such as a chocolate or purple-brown, and finished off with a coat of common varnish, is cheaper than, and as durable as, four coats of colour; it looks better, is more rapidly executed, and stands washing well.

Graining and Varnishing.—In graining, the covering coats (generally a priming and two or three colouring coats) being dry, an even ground is first laid of the general tint of the wood to be imitated, but very much lighter, the pigments being mixed with white lead, oil, and turpentine, which is left to dry for a day or two.

The painter then prepares his pallet board with small quantities of colour similar to the grain of the wood to be represented, ground in oil and mixed with raw oil and turpentine, or, in commoner work, ground in water and mixed with small beer: ale has too much body, and works up on varnishing; this is then laid on the ground, and the shades and graining produced by drawing combs and flat hog's-hair brushes dipped in turps (or in water only, if water colour has been used in place of oil colour) down the fresh-laid colour; for finer work, camel's-hair pencils are required, whilst a piece of cloth or sponge can be used for giving effect to the knots, etc. When dry it should be covered with two coats of copal varnish, one coat, however, being the general rule.

Though graining is dearer than common paint, since it requires great skill to produce first-class work, it will, with an occasional coat of varnish, last very much longer.

The following may be taken as a sample of the materials used in graining, but it must be understood that painters differ as much as doctors in their recipes:—

Maple	Ground	White-lead, stained with red-lead or vermilion, and thinned with one raw oil to two turps.
	Graining	Raw umber or vandyke brown thinned with beer.
Oak	Ground	White-lead, stained with orange chrome, and thinned with one raw oil to two turps.
	Graining	Burnt umber and raw oil, with driers.

Overgraining, which is frequently applied in oak graining as an extra coat, in order to imitate the felt or silver grain seen in Dutch wainscoting, consists of a thin wash of raw umber, or vandyke brown, mixed with small beer, and applied with a large flat brush drawn over the surface with a wavy motion of the hand.

Graining is sometimes done on a coat of size only, so that the natural colour of the wood shows through, thus dispensing with the covering coats and ground; and, with a good coat of copal varnish, this would appear to be a cheap and fairly durable covering for inside work.

Staining and Varnishing.—Varnish, when applied to the natural surfaces of woods, besides acting as a protecting coat, throws up the grain and adds to their ornamental appearance, giving a much more pleasing effect than either plain paint or

graining. The pores of the wood should first be filled up by applying two coats, or at least one coat, of strong glue size, in order to prevent the waste of varnish.

A single coat of gum lac, or good resin, dissolved in linseed oil to about the consistency of cream, and coloured as may be required, also forms a good and durable covering; whilst for common work, not exposed to much wear, as in the case of roof boarding in open roofs, one or two coats of boiled oil alone will suffice. The natural colour of the wood will be slightly darkened when seen through the varnish; but in the case of light-coloured woods, such as deal, it is a very general practice to darken them with stains of different kinds before sizing and varnishing.

All the materials required for staining and varnishing common light-coloured woods in imitation of oak, walnut, mahogany, rosewood, satin-wood, etc., are sold ready prepared for use, amongst which may be mentioned *Stephen's Liquid Stains, imperishable size* and *varnish.* Wood to be treated in this way has to be worked up to a good face, and must therefore be of a better class than if all its defects are to be hidden by paint. When the framing, as in doors, is stained dark, as in imitation of walnut, and the mouldings left unstained, the effect is very good, though of course open to the objection of being but a sham.

A good dark stain for floors and outside work may be made of asphaltum diluted with turps, or of Japan black, or burnt umber and turps. For light tints, turps coloured with raw Sienna, darkened with more or less burnt umber, may be used.

Pitch pine floors stained with Stephen's walnut stain and finished with two coats of oil and turps give a very good effect, and are not slippery.

Painting and Varnishing Plaster.—Plaster to be painted should be finished with well trowelled stucco; or, if necessary, rubbed smooth with pumice-stone, and any holes stopped with plasterer's putty. Being very absorbent, it is often primed with glue size, and then covered with four coats of colour, if the ordinary lead paints are used, and a flatting coat can be added, if desired; but the best plan is to apply a priming coat of boiled oil quite warm, and when dry and hard add a thin coat of weak size tinged with red lead, in order to stop all absorption and give the work a uniform appearance, finishing off with two coats of oil-paint, and a flatting coat if required.

Walls may also be coloured and varnished thus:—First apply,

at boiling heat, two coats of whiting mixed with strong glue size, then fill up defects with mastic in water, and rub smooth with pumice-stone, and cover with two coats of coloured varnish, the first coat mixed with one-fourth of the required colour, and the last coat with only half as much colour; the colour should be ground very fine, and the varnish should be copal varnish.

In painting on plaster, in order to guard against damp injuring the paint, it is safer to distemper the walls for the first two years, and then wash it off, taking care that the walls are perfectly dry before painting. If the distemper is free from grease and dirt, it is better to merely brush it well down with a dry brush, and paint over it, without any washing.

In painting on Portland cement, a wash of Parian or Keane's cement has been suggested, to allow of its being painted without delay.

Painting Iron.—Before painting iron it is essentially necessary that all its surfaces should be perfectly free from rust; for this reason it is better that the surfaces of all new ironwork should be protected from the oxidising effect of the atmosphere, while still hot from the forge or rolls, in the case of wrought-iron, or fresh from the sand in the case of cast-iron, as already explained under the head of "Smith and Ironfounder," see pp. 215, 219, after which a second coat will generally be sufficient to protect the metal; but if no protecting coat has been applied to the iron, all signs of rust should be removed by scraping and brushing with a hard brush, after which two coats of one of the oxide of iron paints (see p. 287), or of the tar paints (see p. 290) will be a sufficient protection against the destructive effects of the air, though for good lasting work as many as four coats should be applied, the two first coats being generally of red-lead and oil when the oxide or tar paints are not used.

Painting Zinc.—In painting on zinc Griffith's, or oxysulphide of zinc, white should be used in place of white-lead, in order to avoid the destruction of the paint by the galvanic action of the lead and zinc.

In order to insure the proper adhesion of paint to zinc it may be treated with a wash, called Mordant, consisting of 16 parts soft water to 1 part of a mixture in equal proportions of chloride of copper, nitrate of copper, sal-ammoniac, and hydrochloric acid.

Painting Paper and Canvas.—Both paper and canvas being

very absorbent should be first well primed with strong glue size, as recommended for plaster; more especially canvas, which would, if primed with oil-paint, be soon destroyed by the oxidising of the oil absorbed into its pores. Old flock papers, well sized and painted, produce an excellent effect upon the walls of a room.

Painting Grates.—Fire grates, when first set, should have one coat of Brunswick black, or some equally good drying and protecting colour.

One of the best mixtures for blacking grates is 4 lbs. of genuine asphaltum, mixed with 1 quart of raw linseed oil and 1 gallon of oil of turpentine.

Japanning.—As the ordinary paints will not stand any great heat, whether dry or wet, a special process called japanning is used for painting baths, cans, and similar articles, as well as for metal work of different kinds.

The surface to be japanned must first be cleaned with oil of turpentine and clean sawdust; or, if a polished surface, with one of sulphuric acid to 20 parts of water, laid on and brushed with a very hard brush; after which, a ground coat is applied, consisting of equal parts of dry whiting, dry or wet white-lead, and litharge, and a small portion of copal, mixed with turps to a thin consistency.

The ground being thoroughly dry, and having been lightly pumiced, the japan is laid on, which may be either turpentine varnish, ordinary shellac lacquer, or japan varnish, made from drying oils and the tougher sorts of resins. If not bright enough a second coat of varnish is applied.

For the methods of japanning bright articles of tin, brass, etc., see volume on *Brass Foundry*, Virtue and Co.'s Series.

Repainting Old Work.—Old paint, when renewed, should have two coats for inside and three for outside work.

In War Department buildings outside painting is allowed to be re-done every four and inside painting every eight years.

In repainting the old paint should be well rubbed down with pumice-stone, and any grease spots removed with turpentine; if much soiled it should be well scrubbed with soap and water, and if smoky and greasy it should be washed with lime and water, well pumice-stoned, and stopped.

Cleaning and Removing Paint.—Old paint can be removed by the tedious process of scraping, or by using a solution of $\frac{1}{2}$

soda and $\frac{1}{2}$ quicklime. The soda is first dissolved in water, after which the lime is added, and the mixture applied hot with a brush, when, after about fifteen minutes, any number of coats can be washed off with hot water. A wash of vinegar should be applied to wood-work before repainting, to kill the lime and prevent its bearing through and injuring the new paint.

Ready prepared mixtures are sold for removing paint, but they are all too expensive to use on a large scale, while none are so effective and rapid in their action as soda and quicklime.

Paint is also burnt off by applying gas jets or a small hand grate to the surface, or by the dangerous plan of washing it over with turps and immediately setting light to it.

Distempering.—The painter also executes superior work in water-colours or distemper, such as colouring inside walls or ceilings, the distemper being laid on cold and about the consistency of trembling jelly.

Washable silicate distempers for internal walls are sold by the Silicate Paint Company under the name of "Duresco." "Silicate Zoppisa," a waterproof wash, sold by the Granitic Paint Company, is intended to render brick and stone walls damp proof. The colourless composition does not materially alter the appearance of the material it is applied to. It is, however, supplied of any desired colour for use as a distemper. It is easily cleaned and does not come off when rubbed against.

For outside walls a colouring coat of whiting and size mixed with boiled oil, and tinted as may be required, is often used as a cheap substitute for ordinary paint.

Common distempering has already been described under the head of Plasterer's Work.

Valuing and Estimating Painter's Work.

The rule in measuring painter's work is to take wherever the brush goes by the *yard super*, in the case of large surfaces such as walls, doors, etc.; by the *foot run* in the case of narrow surfaces *cut in* on both edges, as in skirtings where the paint has to be cut to a line both at top and bottom, to avoid painting the floor or wall; and by the *number* in the case of separate pieces, such as chimney-pieces, newels, balusters, brackets, gratings, etc.

In iron railings and other open work, each side is measured by the yard super as if it were a plane surface; if ornamental, each side is doubled, or a fair extra allowance is made, according to the nature of the work.

The outsides of ordinary-sized frames, being *cut* to the wall, and

the insides as well, when there are no linings as in stores, riding schools, etc., are taken by the number.

In sash frames with mullions or transoms, each division is taken as one side of a frame. The sashes themselves are paid for by the *dozen squares,* the price being for one side only, the number being doubled if painted similarly on both sides.

Letters and figures are paid for by the *inch in height,* as plain or ornamental, no letter being taken at less than an inch, and an inch being allowed for each stop.

Taking Contents from Joiner's Work.—One practice in London is to take out the number of feet super of joiner's work to be painted and to add an eighth, by dividing by eight instead of by nine for the yards super, which makes a fair allowance for edges, etc., and saves the trouble of measuring, whilst it gives a close enough approximation to the true content for the superficial work. If part of the painting is done in a more expensive way than the rest, the yards super can be taken in the same way and an extra charge made on such parts, to cover the difference of cost.

Common and Superior Colours.—The price depends on the nature of the colour or varnish employed; the colours being usually divided into *common* and *superior* colours.

Common colours include *lamp-black, red* and *white lead, Venetian red, umbers,* and all other *common ochres* such as *grays, buffs, stones,* etc.

Superior or *ornamental colours* include *bright yellows, warm tints, blues, mineral greens,* etc.

Some colours, such as *verditer, pea-greens, rich reds, pinks,* and *bright blues,* are charged at a higher rate still, as *delicate tints.*

Estimating Materials.—The following are the yards super which a fixed amount of materials will cover in each coat on wood, arrived at from actual measurement of work done with materials issued from store; it must, however, be borne in mind —in comparing the proportions given by different writers—that the results will always vary according to the skill of the painter, and the proportions according to the quality of the materials employed, more especially of white-lead, which will carry more oil and turps, and therefore cover better, in proportion to its age and purity; pure or genuine white-lead being always the cheapest in the end, owing to its superior covering properties, and the saving of labour in the laying on of the paint; whilst being supplied ready ground in oil, varying in condition from dryness

to a soft paste, it is clear that the amount of thinnings it will carry must vary considerably. Moreover, the thickness of the oil must be taken into account, boiled oil being thicker than raw oil, and age adding thickness to both, and so reducing their covering properties :—

First coat or priming	10 lbs. genuine white-lead 1 oz. red-lead 2 oz. litharge, or $1\frac{1}{2}$ oz. and $\frac{1}{2}$ oz. burnt white vitriol. 4 pints raw linseed oil	63 superficial yards, but varying with the absorbent properties of the surface.
Second coat	10 lbs genuine white-lead. 2 oz. litharge $2\frac{1}{2}$ pints linseed oil $1\frac{1}{2}$ pint spirits of turpentine	100 superficial yards.
Third and fourth coats	10 lbs. genuine white-lead 2 oz. litharge, or $1\frac{1}{2}$ oz. and $\frac{1}{2}$ oz. burnt white vitriol. 2 pints linseed oil 2 pints spirits of turpentine	113 superficial yards.
Flatting coat	10 lbs. genuine white-lead 4 pints turps	150 superficial yards.

The materials given above are for white paint, but for a pure white about $\frac{1}{2}$ oz. of ultramarine blue should be added to the finishing coat.

For coloured paints the last two coats have the colouring pigments, ground in oil, added to the composition in about the proportion of 1 to 2 oz. for every 10 yards of surface to be painted.

Stone colours are obtained by adding to the above ingredients about $1\frac{1}{2}$ oz. of burnt umber and $\frac{3}{4}$ oz. of yellow or spruce ochre, and *lead colours* by adding about 3 oz. of lamp-black, with a little Prussian blue or indigo, according to taste.

For *outside work*, exposed to the weather, less turps should be used in the second coat and none in the subsequent coats, and only *boiled* linseed oil should be employed.

For *inside work* raw linseed is used, but as little as $\frac{1}{4}$ oil to $\frac{3}{4}$ turps should be used for the finishing oil coat, when it is desired to avoid a glossy surface, for the less oil the less gloss.

For *flatting* coats, the colour being ground in oil, only turps is added, as already explained.

One pint of copal varnish will cover about 16 yards; one coat.

Hurst's *Handbook* states that for estimates the following may be taken :—

"One lb. of putty will be required for stopping every 20 to 25 yards super of woodwork.

"One lb. of ordinary lead paint, ready prepared, will cover, on wood, $4\frac{1}{2}$ yards super for the priming coat, $6\frac{1}{2}$ yards for a second coat, and $6\frac{3}{4}$ yards for each succeeding coat. One lb. of prepared red-lead paint will cover, as a priming coat on iron, about $5\frac{1}{4}$ yards.

"One gallon of tar, prepared with 1 lb. of pitch, and applied hot, will cover about 12 yards super for a first coat on wood, and about 17 yards for each succeeding coat. One lb. of prepared oxide of iron paint, applied as a priming coat on iron, will cover from 8 to 12 yards super."

In repainting the rough weather-boarded huts at Shorncliff Camp with Wolston's Torbay paint, received fresh from the works, it was found that, in order to obtain a coat capable of standing the sea-air for four years, the paint had to be laid on very thickly, the following proportions being substituted for those given by the manufacturer:—

56 lbs. of paint to 28 lbs. of oil; 2 raw to 1 boiled, for the first coat; and to 44 lbs. of oil for the second coat.

These proportions, with driers added, gave the following results:—

One lb. of prepared Torbay paint covered 4 yards super in the first coat, and 6 in the second coat,—giving as a time constant, ·14 of an hour per yard super for the first coat, and ·1 for the second coat.

GLAZIER.

The glazier's work comprises *cutting in* or fitting and fixing glass into leadwork or into sashes of wood or iron, as well as *hacking* glass out of old sashes, and cleaning windows.

Sash bars, which are generally of wood, though sometimes of iron, are *fillistered* or rebated on the outside, and the glass is *cut in* or *stopped in* to the rebates, firmly bedded on putty or *back-puttied*, in order to prevent any jar to the frame breaking the glass, and *front-puttied* to keep it in its place.

Tools.

The glazier's tools are as follows:—

Diamond for cutting glass, consisting of an unpolished cut spark set in lead, and attached to a hardwood handle by a

brass ferrule. For cutting plate glass a superior description is required.

Square, straight-edge, rule, and *compasses,* with a socket in one leg to take the handle of the diamond for cutting curves, used in reducing glass to the proper sizes.

Claw hammer for *sprigging,* or securing large panes with small nails called *sprigs.*

Hacking-out knife, generally an old broken knife, sharpened on the edge, for hacking out old putty in reglazing old sashes; as well as a hammer with a hacking edge at back, used for the same purpose.

Stopping knife for stopping in and smoothing off the putty.

Dusting brush for cleaning off.

Sash tool or brush for priming sashes, and making good the paint in renewing glass in old sashes.

Fire, and *copper bolts* or *soldering irons,* for lead glazing.

Materials.

The materials used by the glazier are *glass, putty, paint,* for *priming,* etc., as well as *lead* and *solder* for lead glazing.

Glass used for glazing purposes is distinguished according to the method of its manufacture, as *crown glass, sheet glass,* and *plate glass,* and is described either by its weight per foot super or, in the thicker descriptions, such as plate glass, by its thickness; and may be either flat or bent to any required curve. The sizes of the sheets are limited by the process of manufacture.

Crown Glass.—*Crown* glass, also called Newcastle glass, from the chief seat of its manufacture, is blown in circular tables from 3 feet 6 inches to 5 feet diameter, leaving the boss, from which it was blown, in the centre. The method of blowing it, and bringing it to the required thickness—by making the tube, through which it is blown, revolve rapidly on its axis, causing the glass to run out by centrifugal force from the centre to the circumference of the disc—tends to an inequality of thickness, decreasing from the centre boss to the circumference, as well as to its being more or less striated in concentric rings; thus limiting the size of the good glazing panes which can be cut out of a table.

The qualities [1] of crown glass are known as *selected glazing* or

[1] The quality, weights, and sizes here given are those furnished by the "Glass Tariff" of Messrs. Hartley and Co. of Sunderland.

picture qualities and *usual glazing qualities.* There are two picture qualities, called A for best and B for second best. The usual glazing qualities are divided into *best, seconds, thirds,* and *fourths* or *coarse.* The second quality is used for officers' quarters, etc., thirds for all ordinary barrack purposes, and fourths only for very inferior glazing, such as outhouses, stables, etc.

The weight of crown glass per foot super varies considerably, even in the same table, owing to its decreasing in thickness from the central boss, towards the edges; for windows it should run about 16 oz. per foot super. For every $\frac{1}{16}$ of an inch in thickness it weighs about 13 oz. per foot super.

On an average about 10 or 11 feet super can be cut out of each table, but if cut to the best advantage about 13 feet super can be got from a table, such as is shown in Fig. 276. The sheets are usually cut to about $2\frac{1}{2}$ inches from the centre, leaving a *quarry,* generally 5 by 5 inches, which, having the central boss in it, is chiefly used for stable or similar work. The term *quarries* is also applied to glass cut up into small pieces for lead glazing. There is a difficulty in cutting sheets containing more than 5 feet super.

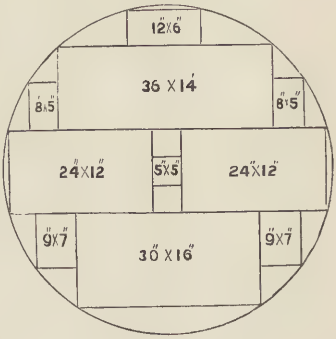


Fig. 276.

Crown glass is sold by the foot super in *crates* of 12 circular *tables* averaging 52 inches in diameter, if of *extra* thickness; or of 18 tables averaging 53 inches, if of the *usual* thickness for glazing. It may also be obtained in flattened slabs, or in squares cut to order, and bent to any curve required. Large squares run more expensive than smaller ones, on account of the greater waste to which the tables cut.

Unflattened is superior in quality to flattened crown glass, but unless specially selected, is so much curved as to necessitate cutting the sash bars, or using a large amount of putty.

On account of the improvement in the manufacture of *sheet glass,* in which the defects inherent to the manufacture of *crown glass* are avoided, the latter is no longer made at many of the large glass works, and is therefore going rapidly out of use; at the same time it is more colourless and less brittle than sheet glass.

Sheet Glass.—*Sheet, flattened sheet, crystal or British sheet,* all signifying the same glass, is used for all ordinary glazing purposes, and is blown in a hollow cylindrical form with closed ends, which when removed leave a glass tube 3 to 4 feet long, and from 10 to 12 inches diameter: these, when cut down one side, are opened up into sheets and flattened out in a reverberatory furnace, and tempered by being cooled gradually in a succession of ovens, each of a lower temperature than the last. It can be polished on face, bent to any curve, or ground on face or edges, as may be ordered.

Sheet glass is either of the ordinary clear description known as crystal, or a light tinted glass is supplied at an increase in cost of about 10 per cent. Crystal sheet glass is generally used for photographic studios, but an extra white quality can be supplied, though at a higher rate.

The *qualities* sold are A and B *picture qualities,* and the usual glazing qualities — viz. *best, second, third,* and *fourth* or *coarse.* The seconds are used for officers' quarters, offices, etc., and thirds for ordinary barrack purposes.

The *weights* per foot super are generally 15 oz., 21 oz., 32 oz., 36 oz., 42 oz., the latter being nearly $\frac{1}{4}$ inch thick. As a rule every $\frac{1}{16}$ inch may be taken as 13 oz. to the foot super.

In *dimensions* the ordinary stock sheets do not exceed 17 feet super, in length 75 inches, or in breadth 45 inches; nor are they less than 10 feet super, 44 inches long, or 34 broad.

Sheet glass is sold by the foot super of the required quality and weight, in *crates* or in *squares* cut to order.

Obscured Sheet.—Obscured or frosted sheet glass is made from any description of the third quality glass, and is known as ground glass, enamelled sheet, and enamelled and ground sheet, the enamelled being cheaper than ground glass, and either plain or in patterns of endless variety.

Fluted Sheet.—Sheet glass of third quality from 15 oz. to 32 oz. per foot super, is rolled, so as to form flutes or corrugations on both sides, which while it secures privacy without obstructing light, makes it much stronger than either ground or obscured sheet glass.

Patent Plate.—*Patent plate* glass is merely a superior class of polished sheet glass, and can be distinguished from *plate glass* by a more wavy appearance of the surface, as well as by the air bubbles, which in sheet glass and patent plate are oval, whilst those in crown and plate glass are circular.

Flattened sheet glass and patent plate should be cut with the convex side of the air-bubbles downwards, or it will be liable to crack starwise, and it should be glazed with the convex face outwards, or it will present the appearance of being hammered on the face.

With regard to the colour of patent plate glass, Messrs. Hartley and Co. of Sunderland, in their trade circular, say: "This glass is of two colours—the usual (*i.e.* crystal), and the extra white, which is almost colourless. For glazing purposes the usual is preferable, as being harder, more lustrous, and less liable to be scratched in cleaning. In these respects patent plate of this kind is as superior to polished plate as it is to that of extra-white colour; but for engravings, water-colour drawings, miniatures, photographic purposes, etc., extra white patent plate is unrivalled."

The *qualities* of patent plate are known as *best* or "B," *second* or "C," and *third* or "C C."

The *thicknesses* and *weights* in each quality of patent plate glass are as follows, viz.: No. 1, averaging $\frac{1}{16}$ inch thick and 13 oz. per foot super; No. 2, $\frac{1}{12}$ inch and 17 oz. per foot; No. 3, $\frac{1}{10}$ inch and 21 oz. per foot; and No. 4, $\frac{1}{9}$ inch and 24 oz. per foot.

The *stock sizes* of sheets are not over, in area 12 feet, in length 50 inches, or in breadth 36 inches.

Plate Glass.—Plate glass is manufactured in thicker and larger sheets than is possible in blown glass; it is very efficient in keeping up the internal temperature of rooms, and is a preventive to robbery, since it will not yield to the diamond and allow of being noiselessly removed.

It is cast on flat tables and rolled out, in which condition it is *rough cast plate.* When brought to the condition of clear window glass it is known as *polished plate.* If the rollers used are ribbed the glass is *ribbed* or *fluted,* and in the same way a *chequered, diamond* (large diamonds are called *quarry patterns*), or any other pattern is produced.

Rough cast plate, or *rough plate,* is the cheapest quality of plate glass, and is cast and rolled into plates even exceeding 100 feet super, but the stock sizes run up to about 60 feet super; its thickness ranges from $\frac{1}{4}$ inch to 1 inch.

It is supplied ground if required, and from its strength is very useful for risers to steps, and for glazing pavements, and similar rough work where light has to be transmitted.

Rough rolled plate, or *rolled plate,* is smooth on one face, and lined or fluted on the other. If over 11 flutes run to the inch it is called *plain* rolled plate; if 11 down to 5 flutes to the inch it is *small fluted,* and under 5 flutes it is *large fluted.*

Plain rolled plate (or plain rough plate) is much used for such purposes as billiard-room lights, conservatories, etc., the fine parallel lines checking the glare of the sun without diminishing the light too much. It is supplied $\frac{1}{8}$ to $\frac{1}{2}$ inch thick, and the stock sheets run up to about 25 feet super, not ever 100 inches in length, though larger sizes can be obtained to order; $\frac{1}{8}$ inch thick is sufficient for panes not over 14 inches wide and 7 feet long.

Ornamental rolled plate (or ornamental figured rolled glass) is an improvement on plain rolled plate, having a better and brighter appearance. It is supplied in endless patterns and in many different tints. Special patterns have characteristic names, such as Lustre, Muranes, Moorish, Morocco, Venetian rippled, Mediæval rippled, etc.

Polished or *British polished plate* is cast and rolled glass polished on both surfaces, though a better description of glass is cast than when intended to be left rough or merely rolled to a pattern.

There are three *qualities: ordinary* and *best glazing*, for windows, and a superior kind called *silvering quality*, for mirrors, etc.

The *stock sheets* run from $\frac{1}{8}$ to 1 inch thick, and up to 100 feet super, 160 inches long or 96 inches wide, but is made in larger sheets if specially ordered.

The best polished plate glass is very clear and colourless. When scratched from wear it can be repolished on face or re-silvered at the back at any glass works, whilst the edges can be ground and polished, if required, or the sheets bent to any curve.

Cathedral Glass.—This shows a rough rolled surface on both faces, and is much used in church work. It is either white or tinted (coated or pot metal) and is mostly rough cast plate, known as *rolled cathedral,* a thinner and dear kind being *sheet cathedral,* made in either 15 or 21 oz. sheet glass.

Coloured Glass.—The best is known as "pot metal," the colour being added in the pot, and the glass coloured right through; it is known as "coated" when merely faced with a thin skin of coloured glass; and "flashed" when coloured with paint laid on and burnt in.

Lights for paving Floors, etc.—*Glass* and *prism lights* and *reflectors,* for gathering and transmitting light through pavements, floors, etc., are extensively used for lighting underground rooms, passages, and cellars. The chief makers at present are Hayward Brothers and Eckstein, Union Street, Borough; and Thaddeus Hyatt, Farringdon Road, London.

Glass Ventilators.—*Perforated panes* of glass, for ventilating purposes, are of two kinds, one having the perforations manu-

factured in the glass, and the other having them afterwards cut; the latter are the best, as the former break very readily.

Hit and miss ventilators, in which the perforations in the pane can be opened or closed by a revolving or sliding glass plate with corresponding perforations, are much used; also glass *louvres,* both fixed and movable. They are manufactured by Moore and Sons, St. James' Walk, Clerkenwell, and H. W. Cooper and Co., Upper George Street, Edgeware Road, London, etc.

Glass Slates and Tiles.—Glass slates and tiles of all kinds are supplied for working in with ordinary tiles and slates, where it is desirable to admit light through the roof covering.

Toughened Glass.—The brittleness of glass can be removed by suddenly plunging it at a cherry red-heat into oil. Glass toughened by some such process has been successfully used even as pot sleepers for carrying rails.

Putty.—The glazier's, like the painter's, putty is merely composed of whiting and raw linseed oil well beaten up.

In order as far as possible to prevent the constant expansion and contraction of large panes of glass from loosening the putty, especially in top lights, tallow is sometimes mixed with it, forming what is called *thermoplastic putty,* which, by retaining its pliability, gives and takes with the glass; but more commonly a small proportion of some fatty non-drying oil is mixed with the putty in order to preserve its pliability; it is manufactured by Sir W. A. Rose and Co., 66 Upper Thames Street, London.

Putty can be removed from old sashes by softening it with a red-hot iron, or after covering it for about twelve hours with a mixture of 1 lb. American pearlash, to 3 lbs. of quicklime, slaked before mixing.

Paint.—The priming and colouring coats used by the glazier are the same as used by the painter.

Lead.—Lead is only used by the glazier for window bars, when the glass is cut up into small panes; it is known in the trade as *fret lead,* and is supplied ready rolled into grooved strips, called *cames.*

Fret lead varies in the width of the grooving, which must be suited to the thickness of the glass, as well as in the width of the cames, and whether flat or round on the face, which depend upon the amount of prominence desired to be given to the bars separating the panes of glass.

Makers of fret lead differ slightly in the dimensions they work

to, but the following table gives a general idea of the sizes of "ordinary," "narrow," and "broad" fret lead, as obtained in the market:—

	Width of Grooves.	Shape of Face.	Width on Face.	Remarks.
Ordinary .	$\frac{3}{32}''$	flat	$\frac{7}{16}''$	Used for ordinary lead lights up to about 21-oz. sheet glass.
Narrow .	$\frac{1}{8}''$	flat	5 widths, from $\frac{3}{16}''$ to $\frac{1}{2}''$	Used for Cathedral and thick antique glass, according to its thickness.
Narrow .	$\frac{3}{16}''$	round	2 widths, from $\frac{3}{16}''$ to $\frac{1}{4}''$	
Broad .	$\frac{1}{4}''$	flat	5 widths, from $\frac{3}{16}''$ to $\frac{1}{2}''$	
Broad .	$\frac{1}{4}''$	round	2 widths, from $\frac{3}{16}''$ to $\frac{1}{4}''$	

Solder.—The solder used for lead glazing is the plumber's *fine solder*, 1 lead to 1 tin.

Execution of Glazier's Work.

Glazing with Putty.—The first operation in *cutting* or *stopping in* glass to wooden sash bars is *priming* the woodwork, or at any rate the rebates which receive the putty, otherwise the wood would draw the oil out of the putty, and cause it to shrink and fall out.

The glass having been cut to fit loosely in the rebates of the sash bars, for when fixed it should nowhere actually touch the frame, otherwise any jar to the sash would be liable to crack it, the *back putty* is then drawn along the inner edge of the rebate, for the back of the glass to bed against; the glass is then put in position, pressed home against the back putty, and *front puttied*, or secured in the rebates by the *front putty* sloping from the inner to the outer edge of the rebate; in doing this care should be taken to keep the putty a little within the inner edge of the rebate, so that none of it may show through the glass from the inside. Both the *front* and *back* putty should then be covered with a coat of paint to protect it from the air, or it would shrink and get loose as the oil dried out of it by oxidation.

The back putty should, when practicable, be left to harden slightly before being trimmed off, to prevent gaps and ragged edges being formed in trimming off with the knife; after hardening, all such imperfections can be remedied by "stopping" before painting.

Care should be taken that the glazing in vertical sashes is upright.

Ground glass should be sized before glazing, or the oil in the putty will disfigure the surface, and cannot be removed.

When large or heavy panes of glass are used, they are further secured in position by small brads or *sprigs* of iron or copper, which are hidden from view by the front putty. Sprigs of an alloy similar to slater's composition nails would be cheaper and as efficient as copper.

The edges of large panes of glass fixed in doors, and other places liable to jars, are often bedded on wash leather.

When the sash bars are inclined, as in skylights, conservatories, etc., horizontal bars are dispensed with, as they would hold the rain, and lead to leakage; the lower edge of each sheet of glass overlaps the upper edge of that next below. In such cases, when large sheets are used, slips of copper or zinc, bent into the form of clips or *tingles*, are hooked on to the head of the lower sheet and turned over the lower edge of the upper sheet, in order to check any tendency to sliding down. Considerable overlap is necessary to prevent leakage, for the overlapping surface can seldom be brought into direct contact, consequently wet is held and drawn up by capillary attraction, and if the lap is not sufficient it will drip over the heads of the under sheets, and moreover, get blown up by the wind; therefore it is better, if possible, to keep the overlapping surfaces far enough apart to prevent any capillary action coming into play. The tails of the panes are frequently cut to a point, or rounded, to throw off the water better, as well as to turn it away from the sash bars. In skylights, lanterns, etc., arrangements should be made to carry off by a small inside gutter, or otherwise, any leakage or condensed moisture which may trickle down the glass on the inside.

Glazing without Putty.—Especially with large glass roofs it is not desirable to trust either to common or to thermoplastic putty, but to have recourse to some system of glazing, in which the glass is not held in its place by putty, thus avoiding all the expenses of repainting and reputtying, as well as the fear of leakage from expansion and contraction, or from the vibration to which railway roofs are so much exposed.

Many different systems of glazing are now in use, which, whilst aiming at freedom from leakage, leave the glass free to expand and contract at the edges; of these, Rendle's patent was the first to be used on a large scale, notably at the Westminster Aquarium.

Figs. 277 to 287 show the most prominent systems advertised at the present time (1885). It will be seen that the carrying off of any water driving round the edges, or condensing on the

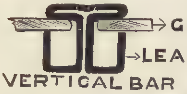


Fig. 277*a*.

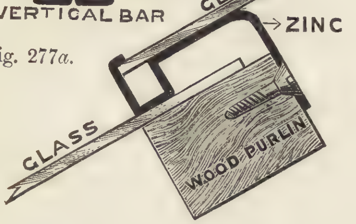


Fig. 277.—Rendle's System.

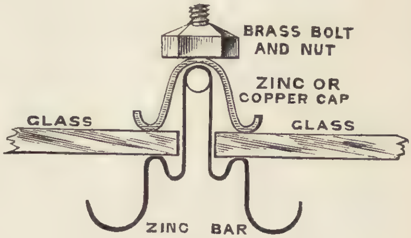


Fig. 278.—Helliwell's System.

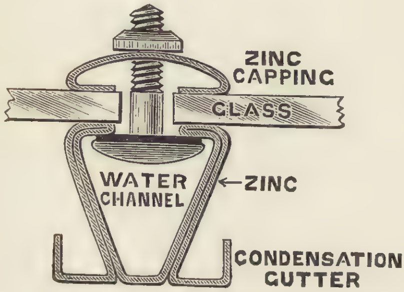


Fig. 279.—Rendle's Invincible.

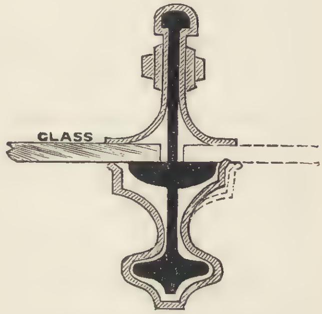


Fig. 280.—Shelley's System.

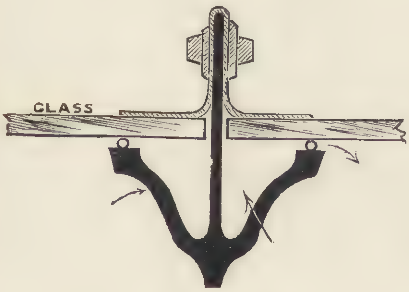


Fig. 281.—Shelley's Standard.

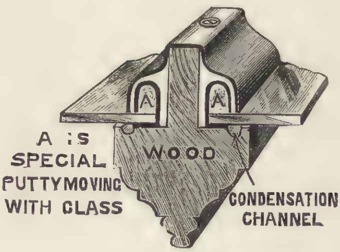


Fig. 282.—Drummond's System.

inside of the glass, is more readily accomplished in some cases than in others; at the same time special circumstances may lead to one system being preferred to another.

Fig. 282 has the advantage of allowing the panes to slide up and down without requiring special sliding sashes.

In Fig. 284 the direct contact of lead and zinc in the presence of rain-water is not, at first sight, suggestive of durability; more-

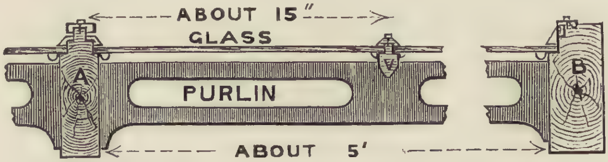


Fig. 283.—Causley's System.

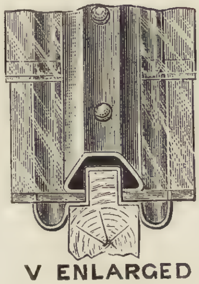


Fig. 283*a*.—Causley's System.

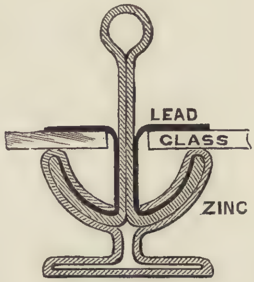


Fig. 284.—Pennycook's System.

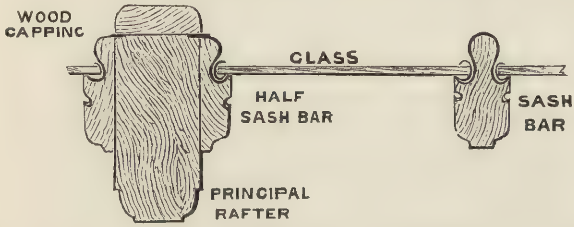


Fig. 285.—Rosser and Russell's System.

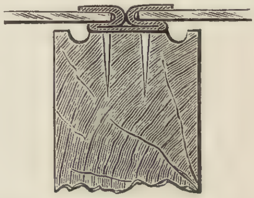


Fig. 286.—Grover & Co.'s.

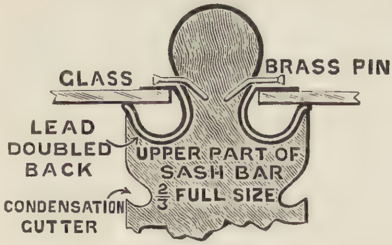


Fig. 285*a*.—Rosser and Russell's System.

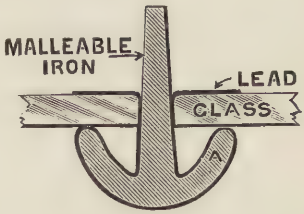


Fig. 287.—Mackenzie's System.

over, very thin lead bent down over the edges of the glass has not been found sufficient to keep the panes from working loose, especially when the wind can get at their undersides. The metal bars shown in Figs. 280, 281, 287, are made strong

enough to carry a board and man for repairs, at their full bearing, without risk of breaking the glass; also the main wooden bars in Figs. 283, 285; whilst special bars can be inserted in the other systems for the same purpose.

A point requiring consideration, in connection with the repairs of large roof surfaces, is the possibility of supporting gangboards without breaking the glass by pressing on its edges. In some of these systems this is an evident defect.

In selecting a system carefully inquire into the actual results of its application to existing buildings; trials of some of them have been made at the Royal Arsenal, Woolwich, at Chatham and Portsmouth Dockyards, etc.

Lead Glazing.—In lead glazing, which is chiefly used in these days for ecclesiastical buildings, the glass is fixed in the grooved edges of narrow leaden bars or *cames,* which are opened up to receive it, and then closed on it firmly.

The *cames* are either soldered together, so as to form squares, diamonds, or other simple figures, or bent to the shapes of the different pieces of glass used in special patterns, in which case it is called *fretwork.*

Large surfaces of leadwork are strengthened by iron *saddle bars,* round which narrow strips or bands of lead, or pieces of copper wire, soldered to the cames, are twisted; and, if required, the saddle bars are themselves strengthened by stout *staybars,* placed at right angles to them.

Measuring, Glazing, etc.—Glazing is measured by the foot super, taking the dimensions from rebate to rebate each way. If cut to a curve or any irregular figure, take the extreme dimensions from out to out; and, in addition, measure the feet run of curved cutting, as *cutting and risk.* Describe the quality of the glass, and whether stopped in old or new sashes.

The price in the War Department Schedules for stopping in old sashes includes one coat of paint to the putty.

Ground edges are paid for by the foot run.

Common glazing in large quantities, as in greenhouses, is measured by the square of 100 feet super, without deducting bars.

Lead lights are measured and valued by the foot super, including all leadwork, but iron *saddles* and *staybars* are taken separately as smith's work.

Panes of glass increase in price with their size, therefore large panes should be avoided in barracks, schools, and similar build-

ings, as the expense of replacing broken glass falls heavily on whoever has to make good such damage.

In writing out requisitions for the repair of glass the following system of specifying the particular panes to be replaced is adopted in the Royal Engineers' Department:—The windows in a room are numbered from the left, as you enter, round to the right, as No. 1, 2, 3, etc., and the panes in each window are numbered from left to right, so that "B house, 5 room, $\frac{2}{7}$," would mean the second window from the left, on entering No. 5 room, B house, and the seventh pane in that window, counting from the top left-hand corner. By this means the pane is readily identified.

PAPER-HANGER.

The paper-hanger's work includes hanging paper, etc.; fixing canvas on battens, to receive paper; sizing and varnishing papers, as in passages and elsewhere; besides stripping off old paper and repairing the walls before repapering.

Tools.

The tools used by the paper-hanger are—a *movable table* on trestles; a *rule* and *scissors;* a *plumb-bob; brushes* and *pots* for paste, size, and varnish; *brush* and *roller* covered with flannel, for smoothing the paper down to the wall; an iron scraper for scraping off old paper and paste; a *pail* and *old stubby paste-brush* for washing walls before repapering; small *trowel* or *stopping tool* for stopping holes with plaster; *needles* for sewing canvas.

Materials.

The materials used by the paper-hanger are *paper* of different kinds, *canvas, tacks, sewing twine, paste, size,* and *varnish.*

Paper.—Paper for wall decoration is sold by the *piece.* A piece of English paper is supposed to be 12 yards long and 20 inches wide when hung, therefore each yard run will contain 5 feet super, and each piece 60 feet super; consequently the feet super of surface to be papered divided by 60 will give the number of pieces of paper required, any odd number of yards being taken as a piece.

With common patterns one piece in ten should be added to make up for waste in cutting and fitting the pattern in; whilst in large patterns one in seven would not be too much. In all cases a liberal allowance should be made, as it is useful for repair, the same pattern not being always procurable when required.

Borders are sold in 12-yard lengths, the same as the papers.

French papers are very much used for superior work, though not in War Department buildings; the pieces vary both in length and breadth, according to the quality of the paper, but are generally 9 yards long and 18 inches wide.

For the more elaborate decorative treatment of walls, panels, doors, etc., new materials are constantly being brought forward; amongst others now in use may be mentioned—*Japanese leather papers,* varying in price from about 15s. to 25s. per piece of about 12 yards by 21 or 36 inches; *Lincrusta Walton,* from about 1s. to 3s. 6d. per yard super; also *Papier-mâché, Carton Pierre,* and *Fibrous Plaster.*

There are three kinds of wall paper in ordinary use, viz.:—*common printed papers, satin papers,* which may be full or half satin, and has the shiny look of satin, and *flock papers,* which have a velvety pattern in relief; the value in each case depending on the number and nature of the colours or *blocks* in each pattern, and increasing considerably on the introduction of gold.

In the cheapest printed papers the pattern only is coloured, the paper itself forming the ground; the better class have coloured grounds. The first two kinds are either hand or machine printed; the hand-made are the best, and may be known by their finish, and by printed dots on the margin, used to mark the position of the blocks. The pattern and colours on cheap machine-made papers soon rub off, from their not being properly set.

Lining Paper.—In superior work, in order to get a very smooth surface for laying paper on, a common white *lining paper,* made in *pieces* similar to ordinary wall papers, is sometimes used; the hanging is paid for by the piece, including pumice-stoning, rubbing smooth, size, and paste. The joints are formed by overlapping the edges of the paper about ½ inch, and are then distempered and rubbed down with a cork and glass paper, in order to prevent their being visible through the wall paper.

India-rubber, gutta-percha, laminated lead, and *tinfoil papers,* have been used as lining papers for walls where damp would be likely to injure the paper; but all these are now superseded by the papers made by the *Willesden Waterproof Paper and Canvas Company,* 34 Cannon Street, London, which are much cheaper, and may even be used by themselves, being supplied in certain colours, besides admitting of being coloured. For lining damp walls, either the 2 ply, 54 inches wide, at 1s. yard run for brown, 1s. 4d. for neutral green, and 1s. 3d. for extra brown; or the 1

ply, 56 inches wide, at 6d. yard run for brown, 7d. for extra stout, and 8d. for neutral green, is recommended.

The drying of walls may be quickened by rubbing them over with sulphuric acid.

Canvas.—On battened walls canvas is sometimes nailed on to battens, to carry the paper. It is resorted to in emergencies when plaster on laths would not dry in time, on thin outer walls, boarded partitions, and when the dampness of the walls renders it advisable to use battens, and a cheaper covering than lath and plaster is desired. It must be well strained, and is valued by the yard super, including sewing, and fixing with tin tacks and brown paper slips over the joints. It is at the best a bad job, being very liable to injury, and getting loose and tight, according to the hygrometric state of the air.

Paste.—Paste is made by mixing the best white sifted wheat-flour with a little cold water, and then gradually adding boiling water, stirring it well all the while to get rid of lumps. A gallon of paste will hang five pieces of English paper, a quart of flour being required for each gallon of paste; sometimes a little alum is used to increase its strength, but it makes it harder and prevents its spreading so well.

One gallon of boiling water to 2 lbs. of flour and 1 oz. of alum is a common proportion in making paste. The thinner the paste can be made the better, and it should be well strained and quite cold before using.

Where great adhesive strength is required, as for the edges of flock papers, add $\frac{1}{2}$ oz. of pounded rosin in place of the alum, and for still greater strength, as for pasting on varnished or painted surfaces, then with gumarabic water instead of merely water.

Size and Varnish.—The size used by the paper-hanger is ordinary glue or gelatine size, as used by the plasterer; the paper should be twice sized, over which is applied one or two coats of copal varnish, mixed with turpentine, or oil if a more durable coat is required. Very choice papers will not stand this operation.

Papers already varnished can now be bought, and are used with advantage where it is desirable to save time and avoid the smell of fresh varnish.

There is a new size called Kilvin's Dry Size, which claims to be colourless and odourless, whereas glue size has a most offensive odour; it is sold in powder, is easily transferable, and can be mixed in any quantity, at any time; it becomes gelatinous on

cooling, after a minute's boiling with a little water, and will keep in the hottest weather several days after mixing. It will not affect the most delicate tints.

Poisonous Papers.—Green papers should be looked upon with suspicion, being frequently coloured with arsenic and poisonous compounds of copper and mercury. The dust from such papers floating in the air is most dangerous to inhale. Suspicious papers should be chemically tested. Some deep greens have been found to contain as much as 70 grains of arsenic per foot super; but arsenic is used for other colours than greens.

Execution of Paper-hanger's Work.

Before papering the ceilings should be finished and the walls should be carefully stopped, pumiced, and sized.

Hanging Paper.—In paper-hanging the trimmed overlapping edges of the paper should face the light to prevent any shadow marking the joints, and should be truly plumb; whilst the pattern should accurately join. In superior work the edges instead of overlapping, are made to butt against each other.

With flock and similar thick papers, about a half a dozen pieces are pasted at a time, in order to allow the paste to soak into them before hanging.

Repapering.—In all cases of repapering walls the old paper should be stripped off and the walls scraped, washed, and stopped, previous to hanging the new paper. Papering over old paper must never be allowed; many rooms which smell close and unhealthy, owe it all to several thicknesses of old paper and paste decomposing on the walls. Disease and deaths have been clearly traced home to the omitting to strip off the old paper before repapering.

Flock papers, when old, instead of being stripped off, may be painted with advantage; they will absorb three or four coats of paint, but should first be primed with two good coats of glue size. The effect produced is very good, from the embossed pattern standing out on the surface.

Measuring and Valuing.

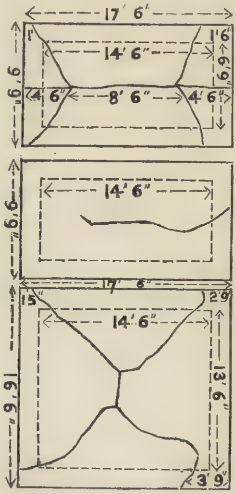
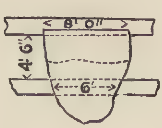
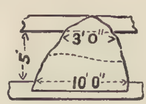
Hanging paper, pumicing and sizing the walls, including paste, is valued by the piece of a dozen yards run. Satin and flock papers cost for hanging about ½d. per yard run, or 6d. per piece,

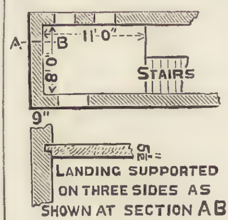
and common papers about 5d. per piece. In bordered papers, or when a border is put round the edges of the paper, the cost of hanging is less than in the case of paper without a border, as the same care is not required in finishing off the edges. Hanging the border is paid for separately by the dozen yards run, paste included.

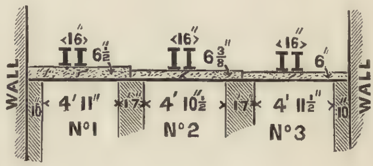
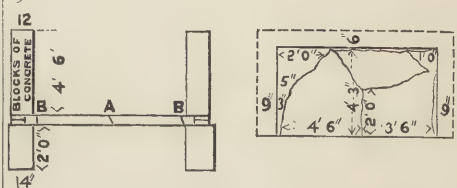
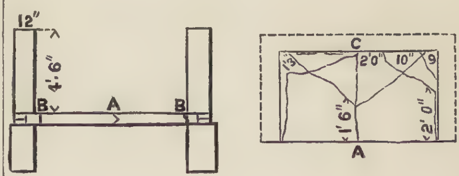
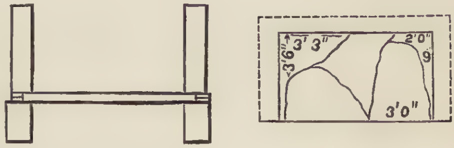
Patterns of different papers authorised for use in the War Department buildings, will be found at all home stations, the paper being supplied by contract, and issued from War Department Stores; they are classed according to their prices, as for "officers' quarters," "field officers," etc. If the occupant of a quarter puts up for his own convenience a paper not of an authorised pattern, or takes it over from a former occupier, he is liable to be called upon to replace it with a regulation paper, on quitting the quarter, unless the next occupier is willing to take it over; and it must also be borne in mind that if damaged, the occupier will be liable to be charged with repapering the whole room, if sufficient of the same pattern cannot be obtained for patching; whereas, with a War Department pattern, the charge might be but trifling for making good the damage.

APPENDICES.

Number of Experiment.	Composition of Concrete.	Size of Slab and how carried.	Time allowed for Setting.	Mode of Testing.
I.	1 Portland cement which had passed the W.D. tests, 4 broken brick ballast (gauged to an inch mesh), and well beaten, covered with water for 7 days.	Thickness 6″, 17′ 6″ × 9′ 9″ out to out, and 14′ 6″ × 6′ 9″ or 98 feet super in the clear, supported on 18″ brick wall all round.	7 days.	Layers of brick piled over the whole of the unsupported surface.
II.	Ditto.	Ditto.	14 days.	Ditto.
III.	Ditto.	Ditto.	21 days.	Covered with 45 men on unsupported portion. Marked time at quick and double, and jumped together; afterwards, loaded with bricks as before.
IV.	Ditto.	Thickness 6″, 17′ 6″ × 16′ 6″ out to out, and 14′ 6″ × 13′ 6″, or 196 feet super in the clear.	21 days.	A party of 80 men marched on to it, marked time at quick and double, then jumped; then loaded with bricks as before.
V.	12 broken brick, 4 of cement, 3 of sand.	Thickness 6″, 17′ 6″ × 9′ 9″ out to out, and 14′ 6″ × 6′ 9″ in the clear.	14 days.	Piled with bricks.
VI.	Ditto.	Ditto.	21 days.	Ditto.
VII.	1 Portland cement, 4 brick ballast as above (No. 1).	Thickness 6″, 18′ 0″ × 16′ 6″ out to out, and 15′ 0″ × 13′ 6″ in the clear.		Weight of 4 cwt. raised over the centre and dropped from a height of 4 feet.
VIII.	Ditto.	*Part of broken slab No. IV. See Column of Remarks, Fig. A.*		2 weights of 56 lbs. dropped together from the following heights:— 4, 6, and 8 feet ... 10 ,, ... 10 ,, ..
IX.	Ditto.	*Part of broken slab No. IV. See Column of Remarks, Fig. B.*		150 lbs. dropped on a 6″ base. 4 and 6 feet ... 8 ,, ... 8 ,, ...

Result.	Remarks.
When loaded with about 11 tons or 2·22 cwts. per foot super, exclusive of its own weight, the edges of the slab began to rise along the sides. When loaded with 15 tons or 3·06 cwts. per foot super, it suddenly gave way.	When supports were removed the water was still dropping through in one or two places. The material seemed too open, 1 of sand suggested to be added, but the results of experiments 5 and 6 do not seem in favour of adding sand; also see Note at end of this Table.
Broke down suddenly when loaded with about 13½ tons or 2·75 cwts. per foot super.	Section wet, and similar in appearance to No. 1. *Cracks in Nos.* 1, 2, 5 *and* 6 *slabs.* 
No result from men jumping. Began to bend with 15 tons or 3·06 cwts. per foot super, rising off outside edges; with 32 tons or 6·53 cwts. per foot super, it cracked slightly; was then loaded up to 43½ tons, or 8·88 cwts. per foot super, without appearance of crack altering. It had tilted up about ¾" at outer edges.	*Crack in No.* 3 *slab.*
No result from men jumping. Slab broke suddenly, and without any warning, under a weight of 10½ tons or 1·07 cwts. per foot super.	*Cracks in No.* 4 *slab.*
Broke under 12 tons 6 cwts., or 2·51 cwts. per foot super, exclusive of its own weight.	The addition of sand does not seem to be advisable.
Broke under a weight of 13 tons 18 cwts. or 2·84 cwts. per foot super.	
Broke a hole clean through the slab, but no radiating crack appeared, nor did the other portion of the slab appear injured.	
Nil. Slight crack at centre. Broken.	Fig. A. 
Nil. Cracked at centre. Sheared through.	Fig. B. 

Number of Experiment.	Composition of Concrete.	Size of Slab and how carried.	Time allowed for Setting.	Mode of Testing.
X.	1 Portland cement, 2 broken Charlbury stone (oolitic limestone), 2 broken brick and Broomhall tiles; some of the stone would only have passed through a $1\frac{1}{2}''$ mesh.		50 days.	A concrete beam weighing 270 lbs. was dropped from a height of 4′ 6″, and fell on one corner in centre of landing. Another beam, 329 lbs. in weight, was dropped from the same height, and fell along one edge about centre of landing.
XI. No. 1 Beam.	1 Portland cement to 4 clean breeze passed through a $\frac{3}{4}''$ mesh.	4′ 11″ in clear × 2′ 6″ × $6\frac{1}{2}''$	43 days old when broken.	Weight applied on 2 wrought-iron girders placed with top and bottom flanges 16″ from out to out.
XII. No. 2 Beam.	2 Breeze, 2 broken brick, 1 cement.	4′ $10\frac{1}{2}''$ in clear × 2′ 6″ × $6\frac{3}{8}''$	Ditto.	Ditto.
XIII. No. 3 Beam.	4 broken brick, 1 cement.	4′ $11\frac{1}{2}''$ in clear × 2′ 6″ × 6″.	Ditto.	Ditto.
XIV.	1 Portland cement, 4 breeze, passed through a $\frac{3}{4}''$ mesh. Cement stood test, after 7 days in water, of from 260 to 545 lbs. per square inch.	8′ × 4′ 3″, clear of supports, × 6″ thick. Fixed as landings, round three sides, see sketch, Column of Remarks.		Loaded all over with bricks.
XV.	Ditto.	Ditto.		Weight of 182 lbs. dropped from a height of 3′ on centre of slab. Ditto, from a height of 4′. Loaded all over with bricks.
XVI.	Ditto.	Ditto.		Loaded at centre.

Result.	Remarks.
Dent, $\frac{1}{8}$" deep. Floor seemed to quiver and 2 or 3 small flakes fell off under side, which was rough. The beam broke in two.	This 6" landing was only run for 4" of its depth into the walls (*see* Fig.) by contractor, but after tests was allowed to pass, and the quarters have been occupied ever since 1877.
A slight line about $\frac{1}{8}$" deep was cut in landing, and a flake or two fell off the under side, but no other effect noticed.	
Deflection $\frac{1}{16}$" with 49 cwt. 0 qr. 4 lbs. Deflection $\frac{3}{16}$" cracked below on soffit with 56 cwt. 2 qrs. 13 lbs. Broke with 66 cwt. 1 qr. 8 lbs. Portion on next wall remained undisturbed.	Sample of cement used gave a breaking weight of 650 lbs. on $2\frac{1}{4}$ sq. ins. after seven days in water. 
Deflection $\frac{1}{16}$" with 24 cwt. 1 qr. 21 lbs. Broke with 26 cwt. 3 qrs. 21 lbs. This beam was disturbed by breaking of Nos. 1 and 3 ; it was not tied at ends.	
Deflection $\frac{1}{4}$" cracked with 28 cwt. 0 qrs. 20 lbs. Broke with 40 cwt. 2 qrs. 3 lbs. Fracture very good ; pieces of brick broken through.	
First cracked at A, then suddenly broke simultaneously at A and B, with distributed load of 37 cwts., or 1·1 cwts. per foot super.	
No effect. Cracked along A C. Broke under $47\frac{3}{4}$ cwts.	
Broke suddenly under 38 cwts.	

Notes on the Foregoing Experiments on Concrete.

Experiments I. to IX. were carried out at the S.M.E., Chatham, in 1874, to test the strength of the floors designed by me for the Brigade Depot Armories.

Experiments XI. to XIII. were carried out by Col. Crozier, R.E., in 1877, at Taunton, to ascertain whether greater strength could not be obtained by using broken bricks instead of coke breeze. The superiority of the breeze was clearly shown.

Experiments XIV. to XVI. were carried out at the S.M.E., Chatham, for the R.E. Committee, in 1880.

In some experiments made for the R.E. Committee, in 1880, with given proportions of Portland cement and gravel, greater strength was obtained, with less time allowed for setting, when the voids in the gravel were only half filled than when completely filled with sand.

APPENDIX II.

(*See page* 24.)

Fireproof Concrete.

The superiority of coke breeze concrete for resisting fire has been proved by practical experiments, see *P. C. E.*, vol. cv., August 1891, "Concrete for Fireproof Structures." The results showed that with concrete blocks composed of 1 Portland cement to 4 coke breeze, weighing 71·65 lbs. per cubic foot, brought to a red heat and then drenched with cold water, the loss of tensile strength was 44·1 per cent; with pumice stone in place of breeze, weighing 64·8 lbs. per foot, the loss was 59·5 per cent; and with firebrick in place of breeze, weighing 95·04 lbs. per foot, the loss was 63·9 per cent.

APPENDIX III.

(*See page* 46.)

Specification for Mortars.

Sand.—To be clean, sharp, pit or freshwater siliceous sand, and to be thoroughly washed and screened, if directed.

Water.—All water used on the works to be clean fresh water.

Lime.—To be freshly burnt, free from under or over burnt pieces and impurities of every kind, and to be in lump unless specified to be ground. It must be kept perfectly dry under cover.

Mixing.—All mortar to be thoroughly well mixed on the site of the works, on a hard banker, which is to be scraped clean before each mixing.

Lime Mortar.—To consist of 1 lime to 3 sand. In the case of lias or other hydraulic lime mortar, no more to be made than can be used the same day.

The lime to be thoroughly slaked without sand, the proportion being measured before slaking.

Cement and Lime Mortar.—To consist of 1 Portland cement to 8 sand, and ½ thoroughly well slaked non-hydraulic lime powder, or just sufficient by trial to prevent the mortar working too short; to be mixed rapidly, the sand and lime first, then the cement added, and used at once.

Cement Mortar.—To consist of 1 Portland cement to 3 washed sand; to be made in small quantities, as required, and used at once, any which may have been mixed for half an hour to be thrown away.

Selenitic Mortar with Ordinary Lime.—To be made in the proportion of 1 bushel of finely ground gray or moderately hydraulic lime to 5 or 6 bushels of sand (6 to 1 works too short for face work) and 3 pints of plaster of Paris. Well mix the plaster in a pail with 2 gallons of water, and pour into a tub or the pan of a mortar mill. Add 4 gallons of water, and when well mixed add a bushel of lime, continuing the mixing till the whole is a creamy paste, then gradually add the sand till the whole is thoroughly incorporated.

If the mortar gets hot or sets too rapidly, use a little more plaster of Paris, but not more than 3½ pints per bushel of lime; if more is required, the lime is unsuitable.

No more to be mixed than can be used the same day.

APPENDIX IV.

(*See pages* 24 and 238.)

SPECIFICATION FOR PORTLAND CEMENT.

Fineness.—To be ground fine enough to pass through the standard sieve of 625 meshes per square inch without leaving any residue, and 90 (or even 95) per cent by weight of the whole must pass through the standard sieve of 2500 meshes per square inch.

Weight and Specific Gravity.—To weigh 87 to 90 lbs. per striked cube foot (or 112 to 116 lbs. per striked bushel) when poured through a hopper with a 2 inch × 2 inch outlet, the top of the cube measure being 6 inches below the outlet; or the specific gravity not be under 2·90.

Pat Test.—Pats ½-inch thick made up of the neat cement must not show any signs of cracking at the edges after setting either in air or water; those in water to be immersed directly the surface water has disappeared in the process of setting, and when broken the section must be uniform in colour and hardness.

Strength.—Briquettes, properly made up of neat cement, with not more than 20 per cent of water, must, seven days after gauging, during at least six of which they must have been immersed in water, be capable of taking a tensile stress of 350 lbs. per square inch before breaking.

Note.—The cement should be moist enough to only allow of being lightly pressed into the mould with the trowel. No heavy pressure or ramming to obtain the highest tensile stress possible should be permitted, and tricks such as placing the briquettes in boiling water for about half an hour before testing, which would greatly add to their tensile strength, should be guarded against.

PETRIFITE.

Petrifite is a new cement of great strength, which, if it realises on a practical scale the results which have been obtained in its experimental stages, bids fair to become of the utmost importance in all branches of the building trades, more especially in all descriptions of concrete work, plasterer's work, and everywhere where a damp-proof, non-absorbent, non-conducting, or wear-resisting surface is required.

APPENDIX V.

(*See page* 24.)

Specification for Concrete in Foundations, Floors, and Roofs.

1. **Aggregate.**—The aggregate in all cases to be perfectly clean and free from clayey, loamy, or organic matter, and to consist of gravel, broken stone, broken brick, or other approved materials, containing not less than $\frac{1}{5}$ and not more than $\frac{1}{3}$ fine stuff. If the fine stuff is insufficient, more must be added, and if in excess, it must be reduced by screening out or adding sufficient coarse stuff to make an approved mixture.

For cement concrete floors and roofs supported on walls or girders the aggregate to be coke breeze from gas works (free from lime and dust or other impurities), well-burnt broken brick, or as otherwise approved, and, if not perfectly clean, to be thoroughly washed.

2. **Mixing, Laying, etc.**—The materials to be carefully measured to the correct proportions in boxes of suitable size, and to be mixed on a clean hard floor by twice turning over dry, and then, while being turned back a third time, watered through a rose sufficiently to make the whole cling together in a pasty mass ; to be then again turned over, wheeled at once in barrows to the site, and gently tipped into position.

If dropped from a height, or shot through a race, it must be again mixed before placing in position.

To be trimmed in layers not exceeding 12 inches, and lightly rammed with a flat wooden rammer until the moisture just comes to the surface.

Each layer to be carried up uniformly, no part being more than 12 inches higher than any other part.

The surface or edges of each layer that has set to be swept clean and well wetted before another layer is added.

The joints of each layer to break joint with those of the layer below.

No traffic of any kind to be allowed over any layer till it is thoroughly hard.

Layers of cement concrete to follow one another rapidly before the last layer has commenced to set ; if a layer has begun to set it must be left to become thoroughly hard before another is added.

An interval of 7 days, or as may be directed, is to elapse between the completion of the concrete foundations and commencing building the walls.

3. **Lime Concrete in Foundations.** — To consist of 7 aggregate, gauged to a $2\frac{1}{2}$-inch ring, to 1 fresh-ground hydraulic lime.

4. **Lime Concrete under Paving, etc.**—Lime concrete in thin layers, continuously supported, as under paving, etc., to consist of 5 aggregate, gauged to a $1\frac{1}{2}$-inch ring, to 1 fresh-ground hydraulic lime.

5. **Cement Concrete in Foundations.**—To consist of 10 aggregate, gauged to a $2\frac{1}{2}$-inch ring, to 1 Portland cement.

6. **Cement Concrete under Paving, etc.**—Cement concrete, in thin layers, continuously supported, as under paving, etc., to consist of 7 aggregate, gauged to a 1½-inch ring, to 1 Portland cement.

7. **Concrete Floors on Solid Ground.**—(*a*) Five inches of dry brick or other approved rubbish to be rammed firm and covered with 5 inches of lime concrete (par. 4) brought to a level surface and finished with 1½ inches of half Portland cement and half fine granite chippings or sharp grit, brought to a level, true, and smooth surface.

(*b*) Five inches of dry brick or other approved rubbish to be rammed firm, covered with 3 inches of cement concrete (par. 6), brought to a level but not a smooth surface, and finished with not less than ½ inch of half Portland cement and half clean coarse sand or sharp grit applied while the concrete is still green, well worked in with a hand float and trowelled to a true and smooth surface.

(*c*) Five inches of dry brick or other approved rubbish to be rammed firm and covered with 4 inches of concrete composed of 5 parts of fine granite chippings to 1 of Portland cement, beaten down to a true and level surface and finished by sprinkling over with neat cement and trowelling perfectly smooth.

8. **Cement Concrete to Upper Floors and Roofs.**—Cement concrete, in thin layers, supported at intervals on walls, girders, etc., to consist of 4 light, porous, aggregate, gauged to a ¾-inch ring, to 1 Portland cement, of the several thicknesses shown on drawings, and laid in not less than one entire bay at each operation, so that no joint may occur except under a support (see footnote), and finished as at (*b*) or (*c*) above; roofs to be finished with ¾ inch of Seyssel or other approved asphalt, in two layers breaking joint with each other.

9. **Concrete under Boarded Floors.**—The ground surface below boarded floors of habitable rooms to have at least 5 inches of brick or other approved dry rubbish, rammed firm and covered with 4 inches of lime concrete (par. 4), roughly floated over with ½ inch of 1 hydraulic lime to 2 sand.

10. **Joints in Concrete Paving.**—Expansion joints to be formed in continuous lengths of paving as directed, and, if not otherwise specified, to be not more than 3 yards apart (see footnote).

11. **Concrete Floors undisturbed, and kept damp.**—Concrete floors must on no account be disturbed while setting; if required to be passed over, planks must be laid down for the purpose.

All centering to be fixed on folding wedges and not to be eased until directed, or for at least 14 days from time of laying.

The surface must be thoroughly protected from the effects of sun or frost, and be kept constantly damp for at least 14 days from time of laying.

12. **Concrete Lintels, or Bricks for fixing Joiner's Work.**—Concrete, when used in place of wood bricks, or wood lintels and rough relieving arches, to be made of 6 clean coke breeze to 1 Portland cement; lintels to be 12 inches longer than the opening and at least 2 inches deep for every foot of span, the minimum depth being 6 inches, with hoop iron bond or W.I. gas tubing imbedded in the soffit, if so specified.

Note.—To guard against cracks in concrete slabs exposed to alterations of temperature, as in roofs and pavements, joints (one inch deep from the surface will do) should be formed at intervals not exceeding 12 feet.

APPENDIX VI.

(*See page* 147.)

TABLES ON STRENGTH OF TIMBER.

IN the following Tables, giving the weights and strengths of different timbers, I have discarded all the records of experiments made on pieces under 2 inches square, as not only untrustworthy but actually misleading; since later experiments have clearly shown that small selected specimens give values, as regards strength, far beyond those obtained from pieces corresponding in size and condition with those used in actual practice.

Moreover, owing to differences in size, form, age, state of dryness, and quality of the specimens, the part of the tree from which they came, the method of testing, and skill of the tester, the results obtained must differ considerably; hence it seems desirable, in the present imperfect state of our knowledge, to give some of the details connected with the experiments, in order that the engineer may not only be able to exercise his judgment in selecting values to suit special cases, but that, by the adoption of some such method of tabulating the records of carefully made experiments, a series of results may by degrees be obtained from which reliable averages, perhaps varying with the scantlings, may ultimately be laid down.

It will be seen that the results here recorded differ very widely, in some cases, from those quoted in most text books; for instance, the tensile strength of northern or red pine, or Baltic fir, is given as from 2240 to 4480 lbs., whereas in Rankine's *Useful Rules and Tables* it is given as from 12,000 to 14,000 lbs., the latter being obtained from tensile experiments made by Barlow on pieces of wood turned down to a diameter of about ·86 inch.

Practical experiments upon timber of the same scantling and quality as that about to be used in any particular case, is preferable to information extracted from tables; but, as such experiments can seldom be made, the engineer should credit his material with the lowest values given in ordinary tables, and then apply a good factor of safety to cover defects in the pieces used, which defects may not have existed in the specimens experimented upon.

EXPLANATORY REMARKS ON TABLES.

If average values taken from the following Table are adopted for timber of fair quality, factors of safety of 3 and 6, for dead and live loads respectively, may be safely used instead of 4 and 8, or 5 and 10, as recommended by Rankine and other writers who were aware that the resistances given in all published Tables, being derived from experiments on very small specimens, would require to be considerably reduced in dealing with larger scantlings.

The differences in the strengths recorded in these Tables are no doubt due, not only to variations in the size and quality of the specimens, but also to their condition as regards seasoning; well seasoned, dry timber being by far the strongest. Hodgkinson found that timber when wet had not half the strength of the same timber when dry; an important point in considering subaqueous structures.

The differences in the weights are chiefly due to the hygrometric state of the specimens weighed, since perfectly dry timber, suitable for joinery, has lost as much as one-third of its original weight; and seasoned stuff, suitable for ordinary carpentry, about one-fifth.

Where, under the head of Crushing Strength, different scantlings are clubbed together, the varying values given were wholly independent of the dimensions, the smaller giving values as high as the larger scantlings.

Authorities Quoted in the Tables.

B. Refers to experiments by Peter Barlow, recorded in his Essay on "The Strength and Stress of Timber." Barlow's formula for the value of the constant determining the transverse strength of a rectangular beam loaded at the centre is $S = \frac{lW}{4b\,d^2}$, whence $\frac{Wl}{4} = Sb\,d^2$; therefore Barlow's S = modulus of rupture ÷ 6; or the modulus of rupture = 6 S. Hence the moduli of rupture given in the Tables, where Barlow is given as the Authority, are obtained by multiplying his value of S by 6. Again Barlow's value of elasticity, E, is = to 4 times the modulus of elasticity, therefore the latter is obtained by dividing the former by 4.

B.B. Refers to experiments made by Mr. H. P. Brereton for Mr. I. K. Brunel.

K. Refers to experiments by Mr. David Kirkaldy.

L. Refers to experiments by Mr. Laslett, given in his "Timber and Timber Trees." Laslett used Barlow's formulæ, hence any moduli of rupture or elasticity given on his authority have been arrived at as stated above, under *B; except that a correction had to be made throughout, as it was found that Laslett, in working out his values of S and E, had taken the total length of the specimen, instead of its length between the supports.*

S.M.E. Refers to experiments made at the School of Military Engineering, Chatham,

W. Refers to experiments made at Woolwich Arsenal.

TABLES.

STRENGTH OF TIMBER.

Description of Wood.	Weight.	Tensile Strength in Direction of Grain.		Modulus of Rupture.	
Seasoned, fit for use, except otherwise stated in Remarks.	Lbs. per Ft. Cube, depending on degree of seasoning.	Lbs. per Sq. Inch.	Number of Specimens, Authority, and Size.	Lbs. per Sq Inch.	Number of Specimens, Size, and Authority.
SOFT WOODS.					
(Resinous and Coniferous.)					
Cedar, Cuban . .	23 to 35—L.	2660 to 3080	4—L. 2″ × 2″	7150 to 8500	6—2″ × 2″—L.
Firs and Pines.					
Spruce or White Fir Riga .	....	....	....	....	....
Spruce or White Fir Canada	28 to 32—L.	3270 to 4760	4—L. 2″ × 2″	7500 to 9700	4—2″ × 2″—L.
Spruce or White Fir Poles .	36 to 38—B.	....	....	8840	3—2″ × 2″—B.
Spruce or White Fir Do. .	....	9070	1—K. 6·75 dia.	10,800	1—6″ dia.—S.M.E.
Northern Pine, also called Red Pine, Baltic Fir, or Red Fir. Dantzic .	32 to 48—L.	2240 to 4480	5—L. 2″ × 2″	9450 to 13,100	6—2″ × 2″—L.
Do. .	....	....	....	3580 to 5920 [2]	4—10″ × 2½″ to 3″—K.
Do. .	....	....	....	3760 to 4750 [2]	2 half timbers—K.
Do. .	....	....	....	3720 to 4790 [2]	5 whole timbers—K.
Do. .	....	....	.....	....	....
Memel . .	34 to 37	....	....	4280 to 6030	4 half timbers—S.M.E.
Do. . .	....	....	....	4450	1 whole timber—S.M.E.
Riga . .	44 to 48—B.	....	....	6300 to 6600	6—2″ × 2″—B.
Do. . .	32 to 37—L.	3080 to 4480	4—L. 2″ × 2″	6720 to 9540	6—2″ × 2″—L.
Swedish best yellow deals	....	....	....	7720 to 8970	5—3″ × 9″—K.
American or Canada Red Pine	40 to 42—B.	....	....	8040	3—2″ × 2″—B.
Do. . . .	33 to 36—L.	1710 to 3320	6—L. 2″ × 2″	7720 to 10,070 7760 to 10,720 [4]	6—2″ × 2″—L. 6—3¼″ × 6″—W.
Do. . . .	....	....	....	7110 to 11,310 [4]	6—2″ × 2″—W.
Pitch Pine . .	39 to 45—B.	....	....	9792	3—2″ × 2″—B.
Do. . .	31 to 58—L.	4200 to 5180	6—L. 2″ × 2″	9380 to 15,000	24—2″ × 2″—L.
Do. . .	....	....	....	5700 to 8150 7610 and 9350	5 whole timbers—K. 2 half timbers—K.
American Yellow Pine	34—B.	....	....	6600	3—2″ × 2″—B.
Do. . .	26 to 37—L.	1800 to 2800	10—L. 2″ × 2″	5650 to 9230	20—2′ × 2″—L.
Do. . .	....	....	....	....	....
Oregon or Douglas Pine	38—L.	....	....	8190 to 12,740 7510 to 10,470	6—2′ × 2″—W. 6—3¼′ × 6″—W.
Kaurie Pine . . (New Zealand)	31 to 35—L.	4060 to 5110	4—L. 2″ × 2″	8500 to 11,800 9950 to 11,920 6160 to 8250	6—2″ × 2″—L. 6—2″ × 2″—W. 6—3¼″ × 6″—W.
Larch, English .	30 to 36—B.	....	....	5000 to 6800	13—2″ × 2″—B.
Do., Russian . .	36 to 43—L.	3390 to 4980	4—L. 2″ × 2″	7800 to 10,000	6—2″ × 2″—L.

Modulus of Elasticity.		Crushing Strength in Direction of Grain.		Remarks.
Lbs. per Sq. Inch.	Number of Specimens, Size, and Authority.	Lbs. per Sq. Inch.	Number of Specimens, Size, and Authority.	
1,003,700	6—2″ × 2″—L.	4050 to 5600	4—2″ Cubes—L.	Honduras and Mexican Cedars weigh about one-sixth more than Cuban.
....	....	1960	1—13″ × 13″ × 20′—K.	Table C.
1,856,700	4—2″ × 2″—L.	4340 to 5040	6—2″ Cubes—L.	
1,458,000	3—2″ × 2″—B.	....	...	
1,799,000	1—6″ dia.—S.M.E.	4220[1]	1—6·75 dia. × 12″—K.	[1] Table K. Excellent quality.
1,020,000 to 1,820,000	6—2″ × 2″—L.	5880 to 7700 5440 to 5790 3920 to 5300 7560 to 9510 3740 to 6110	15—2″ × 2″ × 1″ to 30″—L. 7—3″ × 3″ × 18″ to 15″—L. 14—4″ × 4″ × 15″ to 24″—L. 4—6″ × 6″ × 17″ to 30″—L. 6—10″ × 10′ × 12″ to 21″—L.	
....	....	2500 and 2770[3]	2—9″ × 9″ × 8′—K.	[2] Table A.
....	....	....	....	[3] Table B.
....	....	....	....	
....	....	1742	1—13·5″ × 13·2″ × 21′—K.	Table C.
....	....	....	....	Table D.
....	....	....	....	
990,700 to 1,328,000	6—2″ × 2′—B.	4400 to 5040 3850 to 6440	6—2″ Cubes—L. 13—2″ × 2″ × 3″ to 30″—L.	
1,516,000 to 2,274,000	6—2″ × 2″—L.	2360 2500 4880 to 6236	1—4″ × 4″ × 24″—K. 1—6″ × 6″ × 36″—K. 8 whole timbers, 12′ to 30″ long—L.	Indifferent Timber. Table K.
....	....	....	....	Table A.
1,839,900	3—2″ × 2″—B.	....	....	
1,230,000 to 1,516,000 804,800 to 1,500,800[4]	6—2″ × 2″—L. 6—3½″ × 6″—W.	4480 to 4972	6—2″ Cubes—L.	[4] Table E.
795,370 to 1,629,070[4]	6—2″ × 2″—W.	3200[5]	1—6″ × 6″ × 3′—K.	[5] Table K.
1,225,100	3—2″ × 2″—B.	....	....	
1,516,000 to 2,274,000	24—2′ × 2″—L.	6090 to 6790	6—2″ Cubes—L.	
....	....	....	....	Table A.
1,492,000	3—2″ × 2″—B.	....	....	Table H.
823,500 to 1,820,000	20—2″ × 2″—L.	3780 to 4600	12—2′ × 2″—L.	[6] Large scantlings from 30 to 60 times as long as least dimension, varied from 965 to 1700 lbs., one 12″ × 12″ × 40′ balk, giving as low a resistance as 1065 lbs. per in.
823,530 to 1,890,260	19—6″ × 6″ 12″ × 12″; and 15″ × 15″—B.B.	1570 to 2800[6]	24—6″ × 6″ up to 15″ × 15″; and 9′ up to a length of 20 times least dimension.	
1,184,340 to 1,800,920 1,309,700 to 1,800,140	6—2″ × 2″—W. 6—3¼″ × 6″—W.	....	....	Table F.
1,378,500 to 2,166,200 1,111,000 to 1,779,000[7] 962,570 to 1,892,180[7]	6—2″ × 2″—L. 5—2″ × 2″—W. 6—3¼″ × 6″—W.	5600 to 6700 .... 5270[8]	8—2″, 3″, and 4″ Cubes—L. .... 1—6 × 4″ × 3—K.	[7] Table G. [8] Table K. Excellent quality.
616,000 to 1,050,000	13—2″ × 2″—B.	2610[9]	1—6·18″ dia. × 3′—K.	[9] Green Timber; Table K.
1,450,000	6—2″ × 2″—L.	4850 to 6090	8—2″, 3″, and 4″ Cubes—L.	

Description of Wood.	Weight.	Tensile Strength in Direction of grain.		Modulus of Rupture.	
Seasoned, fit for use, except otherwise stated in Remarks.	Lbs. per Ft. Cube, depending on degree of seasoning.	Lbs. per Sq. Inch.	Number of Specimens, Size, and Authority.	Lbs. per Sq. Inch.	Number of Specimens, Size, and Authority.
HARD WOODS.					
(Non-Resinous and Non-Coniferous.)					
Ash, English	47 to 48—B.	....	....	12,150	3—2″×2″—B.
Do., do.	44 to 47—L.	3780	1—2″ × 2″—L.	11,400 to 11,860	2—2″×2″—L.
Do., Canadian	29 to 39—L.	4060 to 7140	4—2″ × 2″—L.	7830 to 9390	2—2″×2″—L.
Beech	39 to 45—B.	....	....	9330	3—2″×2″—B.
Do.	44 to 45—L.	4850	3—2″ × 2″—L.	....	....
Chestnut	41	10,000 to 13,300	....	10,660	....
Elm, English	33 to 37—B.	....	....	....	....
Do., do.	34 to 43—L.	4620 to 6720	3—2″ × 2″—L.	4320 to 6880	3—2″×2″—L.
Do., Canadian	46 to 48—L.	7980 to 10,570	6—2″ × 2″—L.	12,770 to 12,800	6—2″×2″—L.
Greenheart (British Guiana)	67 to 73—L.	7980 to 9380	3—2″ × 2″—L.	16,360 to 22,350	6—2″×2″—L.
Mahogany, Spanish (Cuban)	45 to 51—L.	2360 to 4950	5—2″ × 2″—L.	10,350 to 12,900	6—2″×2″—L.
Do., Honduras	40 to 42—L.	2480 to 3570	6—2″× 2″—L.	10,120 to 11,490	6—2″×2″—L.
Oak, English	42 to 63—L.	5880 to 8890	6—2″ × 2″—L.	7000 to 10,000 5260 to 13,700	6—2″×2′—B. 24-2″×2″-L.
Do., French	Mr. Laslett's experiments gave results equal to best English Oak.				
Do., Tuscan	Do.	do.	do. weakest English specimens.		
Do., Modena	Do.	do.	do. mean of English specimens.		
Do., Sardinian	Do.	do.	slightly above mean of English.		
Do., Dantzic	48 to 56—L.	3360 to 5460	4—2″ × 2″—L.	6060 to 6860	6—2″×2″—L.
Do., American White	58 to 66—L.	5880 to 7800	5—2″ × 2″—L.	9390 to 11,900	6—2″×2′—L.
Do., do., Baltimore	46 to 51—L.	2730 to 4900	4—2″ × 2″—L.	8460 to 11,300	6—2″×2″—L.
Teak, Burmah or Moulmein	45 to 57—L.	2590 to 4060	6—2″ × 2″—L.	8130 to 13,100	12—2″×2′—L.
Blue Gum, Australia	57 to 69—L.	3640 to 7210	5—2″ × 2″—L.	8320 to 10,350	6—2′×2″—L.
Iron Bark, do.	70 to 73—L.	6720 to 9870	3—2″ × 2″—L.	18,490 to 19,710	4—2″×2″—L.

Modulus of Elasticity.		Crushing Strength in Direction of Grain.		Remarks.
Lbs. per Sq. Inch.	Number of Specimens, Size, and Authority.	Lbs. per Sq. Inch.	Number of Specimens, Size, and Authority.	
1,645,000	3—2′ × 2″—B.	....	....	
1,400,000	2—2″ × 2″—L.	6720 to 7280	4—2″ Cubes—L.	
827,000	2—2″ × 2″—L.	4050 to 7140	4—2″ Cubes—L.	
1,354,000	3—2″ × 2″—B.	....	....	
....	....	7730 to 9360	4—2″ Cubes—L.	Probably from very small specimens.
1,140,000	....	....	....	
699,800	3—2″ × 2″—B.	....	...	
464,200	3—2″ × 2″—L.	5600 to 6040	6—2″ Cubes—L.	
1,300,000	6—2″ × 2″—L.	8500 to 9520	6—2″, 3″, and 4″ Cubes—L.	
1,010,880 to 1,137,240	6—2″ × 2″—L.	15,120 to 15,540 14,150 to 14,430 12,960 to 13,090	3—2″ Cubes—L. 3—3″ do. 3—4″ do.	
1,516,300 to 2,675,800	6—2″ × 2″—L.	6500 to 7800 5400 to 5520 6340 to 6720 5390 to 6540	12—2″ and 3″ Cubes—L. 4—4″ Cubes—L. 2—3″ × 3″ × 11″ and 16—L. 2—4″ × 4″ × 8″ and 13″—L.	
....	....	7480 6300 to 7400 7820 8580	1—12″ × 12″ × 15″—L. 12—2″, 3″, and 4″ Cubes—L. 1—9½″ × 9½″ × 15″—L. 1—9½″ × 9½″ × 18″—L.	
873,700 to 1,451,500 568,620 to 1,516,320	6—2″ × 2″—B. 24—2″ × 2″—L.	7000 to 8050 3920 to 5320 7630 to 8820 5450 to 5780 3290 to 4200 3946 7600 6400 4200, 3300, 3040	18—2″, 3″, and 4″ Cubes—B. Do. do.—L.[10] 12—2″ × 2″, × 2″ to 12″—L. 3—2″ × 2″ × 9″, 18″, 24″, and 30—L. 4—3″ × 3″ × 17″ and 18″—L. 9—3″ × 3″ × 8″ to 16″—L. 10—4″ × 4″ × 15″ to 24″—L. 2—6″ × 6″ × 3′—K.[11] 2—6″ × 6″ × 24″ and 36″—L. 3—9″ × 9′ × 15″, 18″, and 21″—L. 1—9″ × 9″ × 8′, 10″ × 10″ × 8′, and 12″ × 12″ × 8′—K.[12]	[10] These Cubes were unseasoned These were not well seasoned. [11] Very good; Table K. [12] Table B.
395,400 to 528,900	6—2″ × 2″—L.	6850 to 7410	8—2″, 3″, and 4″, Cubes—L.	
909,800 to 1,516,000	6—2″ × 2″—L.	6720 to 7270 5600 and 4480 6490 5150	6—2″ Cubes—L. 1—3″ and 4″ Cubes—L. 1—9″ × 9″ × 15″ and 24″—L. 1—12″ × 12″ × 30″—L.	
1,230,000 to 1,819,500	6—2″ × 2″—L.	5670 to 6040	6—2″ Cubes—L.	
722,000 to 1,684,000	12—2″ × 2″—L.	4480 to 6040 4240 to 5880 7620 to 10,820 7630 to 8900	6—2″ Cubes—L. 10—4″ × 4″ × 15″ to 24″—L. 7—6″ × 6″ × 12″ to 30″—L. 7—9″ × 9″ × 12′ to 30″—L.	
1,300,000 to 2,274,480	....	5880 to 7630	6—2″ Cubes—L.	
2,274,480 to 2,675,800	....	9860 to 10,640	4—Do.	

Tables for Strength and Deflection of Baltic Fir Beams.

The following labour-saving Tables (No. III. drawn up by Captain H. M. P. R. Sankey, R.E.), will be found useful in practice. They are based on the practical experiments quoted in Table I.

TABLE III.

Central dead Load, in cwts., that will break a Rectangular Beam of Northern Pine or Baltic Fir 1″ broad, supported at both ends.

Span in Feet.	Depth in Inches, and centre breaking Load in Cwts.											
	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″
	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
4	5·62	10·0	15·62	22·5	30·62	40·0	50·62	62·5	75·62	90·0	105·62	122·5
6	3·75	6·67	10·42	15·0	20·42	26·67	33·75	41·67	50·42	60·0	70·42	81·67
8	2·81	5·0	7·81	11·25	15·31	20·0	25·31	31·25	37·81	45·0	52·81	61·25
10	2·25	4·0	6·25	9·0	12·25	16·0	20·25	25·0	30·25	36·0	42·25	49·0
12	1·87	3·33	5·21	7·5	10·21	13·3	16·87	20·83	25·21	30·0	35·21	40·83
14	1·61	2·86	4·46	6·43	8·75	11·43	14·46	17·86	21·61	25·71	30·18	35·0
16	1·41	2·5	3·91	5·62	7·66	10·0	12·66	15·62	18·91	22·5	26·41	30·62
18	1·25	2·22	3·47	5·0	6·8	8·89	11·25	13·89	16·8	20·0	23·47	27·22
20	1·12	2·0	3·12	4·5	6·12	8·0	10·12	12·5	15·12	18·0	21·12	24·5
22	1·02	1·82	2·84	4·09	5·57	7·27	9·2	11·36	13·75	16·36	19·20	22·27
24	0·94	1·67	2·6	3·75	5·1	6·67	8·44	10·42	12·6	15·0	17·60	20·42
26	0·86	1·54	2·4	3·46	4·71	6·1	7·79	9·61	11·63	13·85	16·25	18·85
28	0·8	1·43	2·23	3·21	4·37	5·71	7·23	8·93	10·8	12·86	15·09	17·5
30	0·75	1·33	2·08	3·0	4·08	5·33	6·75	8·33	10·08	12·0	14·08	16·33

Load calculated from $\frac{Wl}{4} = \frac{rI}{y} = \frac{rbd^2}{6}$ for rectangular sections; where

W = Central dead load in cwts. that will break a rectangular beam.

l = Length of span in inches. b and d = Breadth and depth, in inches.

r = Modulus of rupture for fir in large scantlings, = $2\frac{1}{4}$ tons = 45 cwt. or 5040 lbs.

I = Moment of inertia of section.

y = Distance of extreme fibres from neutral axis of section.

Example—To find the B.W. (breaking weight) of a beam of Memel fir, 18′ span, 6″ deep, and 12″ broad.

B.W. for 1″ in breadth, given in Table, is 5 cwt.

$\therefore$ B.W. of beam = 5 × 12 = 60 cwt.

If the span is 19′; mean B.W. for 1″ = $\frac{5 + 4·5}{2}$ = 4·8 cwt. nearly.

$\therefore$ B.W. of beam = 4·8 × 12 = 57·6 cwt.

For beams supported both ends, loaded uniformly. ,, *fixed one end, supported at the other, load uniformly distributed.* ,, *fixed both ends, load at centre.*	Multiply B.W. in Table by 2.
,, ,, *loaded uniformly.*	Multiply B.W. by 3.
,, *fixed one end, free at the other, load uniformly distributed.*	Divide B.W. by 2.
,, *fixed one end, loaded at the other.*	Divide B.W. by 4.

TABLE IV.

Distributed dead Loads, in cwts., which will produce a deflection, V, of $\frac{1}{40}$ of an inch per foot run of span, on Rectangular Beams of Northern Pine or Baltic Fir 1″ broad, supported both ends.

Span in Feet.	Depth in Inches, and distributed Load in Cwts.											
	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″	13″	14″
	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
3	3·57	8·46	15·41	28·56	45·35	67·69	96·39	132·2	175·9	228·48	290·49	362·82
4	2·01	4·76	9·29	16·86	25·56	38·08	54·22	74·37	98·99	128·52	163·4	204·09
5	1·29	3·04	5·95	10·28	16·33	24·37	33·9	47·6	63·35	82·75	104·52	136·11
6	·89	2·12	4·13	7·14	11·26	15·72	24·7	33·05	45·11	57·12	72·52	90·7
7	·65	1·55	3·04	5·24	8·33	12·45	17·7	22·04	32·32	41·96	53·35	66·64
8	·5	1·19	2·32	4·01	6·37	9·63	13·55	18·6	24·74	32·13	40·85	50·88
9	·39	·94	1·83	3·17	5·04	7·52	10·71	14·69	19·35	25·38	32·28	40·2
10	·32	·76	1·48	2·57	4·08	6·09	8·67	11·9	15·84	20·56	26·14	32·65
11	·26	·63	1·23	2·12	3·38	5·04	7·17	9·83	13·09	16·1	21·01	26·91
12	·22	·53	1·04	1·78	2·83	4·23	6·03	8·26	10·99	14·28	18·15	22·61
13	·19	·45	·88	1·52	2·41	3·61	5·13	7·04	9·39	12·16	15·47	19·37
14	·16	·39	·76	1·31	2·04	3·11	4·43	6·07	8·08	10·49	13·34	16·62
15	·14	·34	·66	1·14	1·81	2·71	3·85	5·29	7·03	9·14	11·62	14·56
16	·12	·29	·58	1·00	1·59	2·38	3·38	4·6	6·19	8·03	10·21	12·75
17	·11	·26	·51	·89	1·41	2·12	3·00	4·12	5·48	7·11	9·05	11·29
18	·10	·23	·46	·79	1·26	1·82	2·6	3·67	4·89	6·35	8·07	10·08
19	·09	·21	·41	·71	1·13	1·69	2·40	3·29	4·38	5·69	7·2	9·05
20	·08	·19	·37	·64	1·02	1·52	2·17	2·97	3·96	5·12	6·54	8·16
21	·07	·17	·34	·58	·9	1·38	1·97	2·67	3·59	4·66	5·95	7·4
22	·07	·15	·31	·53	·84	1·25	1·79	2·46	3·2	4·25	5·4	6·76
23	·06	·14	·28	·48	·77	1·15	1·64	2·25	2·99	3·89	4·95	6·17
24	·06	·13	·25	·44	·71	1·56	1·51	2·06	2·75	3·57	4·54	5·67
25	·05	·12	·23	·41	·65	·97	1·39	1·9	2·53	3·29	4·18	5·22
26	·05	·11	·22	·38	·6	·9	1·28	1·76	2·34	3·04	3·87	4·83
27	·05	·1	·2	·35	·56	·83	1·19	1·63	2·17	2·82	3·59	4·48
28	·04	·1	·19	·32	·51	·77	1·11	1·52	2·02	2·62	3·33	4·16
29	·04	·09	·18	·30	·47	·72	1·03	1·46	1·88	2·44	3·11	3·88
30	·04	·09	·16	·28	·45	·67	·96	1·32	1·76	2·28	2·9	3·63

$$V = \frac{nWl^3}{EI}\ ;\ \text{or}\ \frac{L}{40}\ \text{inches} = \frac{5}{384} \cdot \frac{WL^3 12^3}{\frac{1,440,000}{112} \times \frac{bd^3}{12}}.$$

Whence, W cwts. $= \frac{1 \cdot 19 bd^3}{L^2}$; from which formula Table V. was drawn up by Lieut. A. R. Sankey, R.E.

W = total distributed dead load in cwts. on a fir beam supported both ends, the deflection being limited to $\frac{1}{40}''$ per foot run of span.
b and d = breadth and depth in inches.
L = length of span in feet ; l = ditto in inches.
E = modulus of elasticity, taken at 1,440,000 lbs.
I = moment of inertia of rectangular section $= \frac{bd^3}{12}$.

For beam supported both ends, load at centre,	multiply value of W by		$\frac{5}{8}$.
.. *fixed both ends, load uniform,*	,,	,,	5.
.. ,, ,, *load at centre,*	,,	,,	$\frac{5}{2}$.
.. ,, [1] *as cantilevers, load uniform,*	,,	,,	$\frac{5}{24}$.
,, ,, ,, *load at outer end,*	,,	,,	$\frac{5}{64}$.

With ordinary timber it would be safer to take about $\frac{5}{6}$ of the uniform loads in Table IV., which is equivalent to adopting a modulus of elasticity of 1,210,000 lbs., giving the simple formula for a supported beam, deflection limited to $\frac{\text{span}}{480}$, of W cwts. $= \frac{bd^3}{L^2} = \frac{ad^2}{L^2}$.

[1] In beams fixed one end and free at the other the limiting deflection is $\frac{1}{20}$, instead of $\frac{1}{40}$, of an inch per foot run of their length.

Results of Experiments made by Mr. David Kirkaldy on the Breaking Strength of the Woods proposed to be employed in constructing a granary at the Surrey Commercial Docks, London.

TABLE A.

Name of Wood.	Size.	Span.	Ultimate strength, load at centre.	Modulus of Rupture.	Remarks.
Pitch Pine .	13″ × 14″	12 feet.	80,520 lbs.	6823	Mean value of modulus of rupture = 7500 lbs.
,, .	12″ × 12″	,,	65,215 ,,	8152	
,, .	12″ × 12″	,,	59,244 ,,	7405	
,, .	13″ × 13″	,,	74,620 ,,	7347	
,, .	13″ × 13″	,,	57,972 ,,	5700	
,, .	6″ × 12″	,,	37,424 ,,	9356	
,, .	5·9″ × 12″	,,	30,456 ,,	7615	
Dantzic . .	13″ × 13″	,,	41,448 ,,	3717	Mean value of modulus of rupture = 4340 lbs.
,, . .	13″ × 12·9″	,,	39,956 ,,	3774	
,, . .	13″ × 12·9″	,,	38,672 ,,	3683	
,, . .	12″ × 12″	,,	38,336 ,,	4792	
,, . .	12″ × 12″	,,	37,948 ,,	4746	
,, . .	6″ × 12″	,,	18,974 ,,	4746	
,, . .	5·95″ × 12·05″	,,	15,043 ,,	3762	
,, . .	3″ × 10″	,,	7,512 ,,	5408	Mean modulus of rupture = 4620 lbs.
,, . .	2½″ × 10″	,,	6,849 ,,	5918	
,, . .	3″ × 10″	,,	4,997 ,,	3598	
,, . .	2¼″ × 10″	,,	4,156 ,,	3585	
Gefle Fir .	3″ × 9″	,,	10,098 ,,	8976	Mean modulus of rupture = 8200 lbs.
,, .	3″ × 9″	,,	9,667 ,,	8592	
Swedish DDD.	3″ × 9″	,,	8,954 ,,	7960	
,, SS .	3″ × 9″	,,	8,728 ,,	7758	
,, HB .	3″ × 9″	,,	8,684 ,,	7720	

TABLE B.

Name of Wood.	Size.	Crushing Strength.	
		Lbs. per inch.	Tons.
Oak Posts	12″ × 12″ × 8′	3,040	197
,, ...	10″ × 10″ × 8′	3,300	148·6
,, ...	9″ × 9″ × 8′	4,200	153
Dantzic Posts	9″ × 9″ × 8′	2,500	90·6
,, ...	9″ × 9″ × 8′	2,770	100·2

TABLE C.

Results of Experiments to ascertain the resistance to a gradually increased thrusting stress of a log of White Riga Fir and one of Red Dantzic Fir. Length, exactly 20 feet, ends cut square.

Scantling—White, end, 13·5 × 13·0 ; centre, 13·0 × 13·0 = 169 square inches area ; end, 12·8 × 13·0. Red, end, 13·5 × 13·0 ; centre, 13·5 × 13·2 = 178 square inches area ; end, 13·5 × 12·5.

(See Transactions of R.I.B.A., 1871-72—Paper by Captain H. C. Seddon, R.E.)

Description.	Total stress in lbs.—Depression inch.																		Ultimate stress.	
	20,000	30	40	50	60	70	80	90	100,000	150,000	200,000	250,000	260	270	280	290	300,000	310	320	330,000	Total lbs. Total tons.	Lbs. per sq. inch. Tons per sq. foot.
White Riga .	·032	·058	·083	·103	·122	·140	·158	·176	·194	·273	·358	·434	·455	·4 3	·492	·508	·523	·540	·565	·642	331,260 lbs.	1960 lbs.
(Test No., A 1349.)	Set								·010	·014	·016						·022				147·88 tons.	126·04 tons.
		Deflection horizontally.							·34	·41	·47	·53					·64					
		,, vertically.							0	0	0	0					0					
Red Dantzic .	·035	·062	·088	·111	·133	·150	·170	·188	·2 3	·276	·346	·414	·440	·469	·488	·507	·548	...	...	...	309,120 lbs.	1742 lbs.
(Test No., 1350.)	Set										·020						·033				138·00 tons.	112·02 tons.
		Deflection horizontally.							·08		·19	·25					·47 ·08					
		,, vertically.							·10		·22	·29					·55 ·11					

A 1349 gave way at knots 2′ 9″ off centre ; 1350 at knots 0′ 9″.

Between 150,000, 200,000, and 250,000 lbs. every addition of 10,000 lbs. increased the deflection by ·015 to ·018 in the case of the White Riga, and from ·01 to ·018 in the case of the Red Dantzic log, following no regular order.

TABLE D.

RESULTS of EXPERIMENTS made at the S.M.E., Chatham, to determine more accurate coefficients of rupture for timber of large scantling.

Five baulks of Memel fir were tested. The timber was of good quality, such as is sold in the market for building purposes. It contained no large knots or other defects.

No. of Experiment.	Span.	Depth.	Breadth.	Central breaking weight lbs.	Corresponding Modulus of Rupture lbs. per sq. inch.	REMARKS.
1	17′	12″	12″	25,120	4,448	Mean value of modulus of rupture = 5162 lbs.
2	19′·1″	5·5″	12″	4,520	4,281	These beams were cut from a 12″ × 12″ baulk.
3	19′·1″	6·2″	12″	8,090	6,030	
4	19′	6″	12″	6,750	5,344	
5	19′	5·75″	12″	6,620	5,706	

From this Table it appears that not only is the strength of timber of the same quality very variable, but also that the two halves of the same log are by no means of the same strength (vide examples 2 and 3, 4 and 5).

TABLES E, F, G.

MODULI of RUPTURE and ELASTICITY derived from experiments made at the Royal Laboratory, Woolwich, in 1873, with the object of selecting a wood for the superstructure of the military pontoon bridges. Kawrie pine, though well suited for the purpose, was not obtainable in the market in sufficient quantities.

TABLE E.

CANADA OR AMERICAN RED PINE.						
Size and bearing of baulks.	**Number of Baulk.**	**Total weight of Baulk.**	**Central breaking weight.**	**Deflection.**	**Modulus of Rupture.**	**Modulus of Elasticity.**
		lbs.	lbs.	inches.		
6″ × 3¼″ × 14′ 3½″	1	71	4,032	6½	8,870	1,114,280
	2	75½	4,872	6	10,718	1,458,600
	3	78	3,528	5½	7,761	1,152,280
	4	79	3,864	4⅝	8,500	1,500,790
	5	70	3,696	8¼	8,131	804,770
	6	77	4,144	6⅞	9,116	1,082,780
	Average	7	4,022	6·3	8,849	1,185,600
2″ × 2″ × 6′ 0″	7		679	3¼	9,166	1,218,440
	8		838	3	11,313	1,629,070
	9		660	3⅞	8,190	993,320
	10		772	3¼	10,422	1,385,320
	11		716	5¼	9,666	795,370
	12		527	3	7,114	1,024,490
	Average		698·8	3·6	9,312	11,744,330

TABLE F.

Size and bearing of Baulks.	Number of Baulk.	Total weight of Baulk.	Central breaking weight.	Deflection.	Modulus of Rupture.	Modulus of Elasticity.
Oregon or Douglas Pine.						
		lbs.	lbs.	inches.		
6″ × 3¼″ × 14′ 3½″	13	94	4,592	$4\frac{3}{4}$	10,102	1,736,800
	14	$79\frac{1}{2}$	3,584	$4\frac{1}{2}$	7,884	1,430,700
	15	$83\frac{1}{2}$	4,648	$6\frac{3}{8}$	10,225	1,309,700
	16	70	3,696	$4\frac{3}{4}$	8,131	1,397,800
	17	95	4,760	$4\frac{3}{4}$	10,472	1,800,140
	18	$67\frac{1}{2}$	3,416	$4\frac{5}{8}$	7,515	1,676,350
	Average	81·6	4,116	4·96	9,055	1,558,580
2″ × 2″ × 6′ 0″	19		912	3	10,312	1,772,930
	20		772	$2\frac{1}{2}$	10,422	1,800,920
	21		377	$3\frac{5}{8}$	11,839	1,410,940
	22		709	$3\frac{1}{8}$	9,571	1,323,160
	23		944	$3\frac{3}{8}$	12,744	1,631,230
	24		660	$3\frac{1}{4}$	8,190	1,184,340
	Average		812·3	2·93	10,846	1,520,580

TABLE G.

Size and bearing of Baulks.	Number of Baulk.	Total weight of Baulk.	Central breaking weight.	Deflection.	Modulus of Rupture.	Modulus of Elasticity.
Kawrie Pine.						
		lbs.	lbs.	inches.		
6″ × 3¼″ × 14′ 3½″	25	$76\frac{1}{4}$	2,800	$3\frac{1}{4}$	6,160	1,547,640
	26	70	3,304	$3\frac{7}{8}$	7,268	1,531,710
	27	72	3,136	$4\frac{3}{4}$	6,899	1,185,980
	28	77	3,584	$4\frac{1}{4}$	7,884	1,514,860
	29	$71\frac{1}{2}$	3,416	$6\frac{3}{8}$	7,515	962,570
	30	78	3,752	$3\frac{9}{16}$	8,254	1,892,180
	Average	73·16	3,332	4·34	7,330	1,429,150
2″ × 2″ × 6′ 0″	31		762	4	10,287	1,111,000
	32		883	$3\frac{5}{8}$	11,920	1,420,590
	33		..	..	..	..
	34		835	$2\frac{7}{8}$	11,272	1,693,800
	35		737	3	9,949	1,432,730
	36		877	$2\frac{7}{8}$	11,839	1,779,010
	Average		818·8	3·25	11,053	1,491,420

TABLE H.

TIMBER CRUSHING AND DEFLECTIONS.

American Yellow Pine (specified to be of Quebec or Upper Port Growths).

ANALYSIS OF EXPERIMENTS MADE FOR MR. I. K. BRUNEL IN 1846.

Printed by Permission of R. P. Brereton, Esq., M.I.C.E.

	Breadth. Depth.	Proportion of base to length.		Crushing weights.	Per sq. inch.	Compression under endway stress. With half breaking weights.	Compression under endway stress. Proportion of length.	Deflection under transverse stress. Weight at centre.	Deflection under transverse stress. Deflection.	Bearing.	[1] Modulus of Elasticity.
Ft.	In. In.			Tons.	Tons.	Ins.		Tns.	Ins.	Ft.	
9	8 × 8	1 : 13·5	·074	74	1·10						
9	8 × 8	1 : 13·5	·074	61½	·96	·15	·0014				
9	8 × 8	1 : 13·5	·074	61½	·96	·15	·0015				
9	9 × 9	1 : 12	·083	56½	·70	·15	·0014				
9½	8 × 8	1 : 14	·071	60	·93	·10	·0009				
9½	9 × 9	1 : 12·5	·080	70	·86	·07	·0006				
9½	9 × 9	1 : 12·5	·080	60	·76	·12	·0011				
10	6 × 6	1 : 20	·050	35	·97	·09	·0007	1	·50	10	1,493,330
10	6 × 6	1 : 20	·050	45	1·25	·04	·0003	1	·67	10	1,114,420
10	9 × 9	1 : 13·5	·074	90	1·10	·08	·0006				
10	9 × 9	1 : 13·5	·074	80	·88	·08	·0006				
10	12 × 12	1 : 10	·100	120	·83	·08	·0006	2	·09	10	1,037,030
10	12 × 12	1 : 10	·100	120	·83	·10	·0008	3	·17	10	823,530
10	14 × 13½	1 : 8·5	·118	165½	·87	·09	·0007				
10	14 × 14	1 : 8·5	·118	160	·82	·08	·0006				
10	15 × 15	1 : 8	·125	230	1·02	·09	·0007				
10	15 × 15	1 : 8	·125	260	1·15	·09	·0007				
19	8 × 8	1 : 28·5	·035	54½	·85	·29	·0013				
19½	8 × 8	1 : 29	·034	42½	·66	·26	·0011				
19	9 × 9	1 : 24	·042	88	1·10	·19	·0008				
19	9 × 9	1 : 24	·042	55½	·68	·17	·0007				
20	9 × 9	1 : 26·5	·038	90	1·11	·17	·0007				
20	12 × 12	1 : 20	·050	130	·93	·20	·0008	2	·52	20	1,435,900
20	12 × 12	1 : 20	·050	100	·70	·21	·0009	1	·42	20	888,890
20	14 × 14	1 : 17	·059	150	·76	·16	·0006				
20	14 × 14	1 : 17	·059	190	·96	·17	·0007				
20	15 × 15	1 : 16	·063	180	·80	·19	·0008	2	·305	20	1,002,730
20	15 × 15	1 : 16	·063	240	1·06	·22	·0009	2	·32	20	955,730
20	15 × 15	1 : 16	·063	220	·98	·17	·0007	2	·28	20	1,092,260
29	8 × 8	1 : 43·5	·023	37	·58	·20	·0006				
29	9 × 9	1 : 40	·025	45	·55	·18	·0005				
30	12 × 12	1 : 30	·033	100	·70	·27	·0007	1	1·10	30	1,145,450
30	12 × 12	1 : 30	·033	80	·55	·12	·0003	1	·87	30	1,448,280
30	14 × 14	1 : 25·5	·039	210	1·07	·32	·0009				
30	15 × 15	1 : 24	·042	160	·70	·28	·0008	2	·61	30	1,692,110
30	15 × 15	1 : 24	·042	200	·88	·11	·0003	2	·69	30	1,495,930
30	15 × 15	1 : 24	·042	180	·80	·30	·0008	2	1·05	30	983,040
39	8 × 8	1 : 58·5	·017	30	·48	·15	·0003				
39	9 × 9	1 : 52	·019	35	·44	·18	·0004				
39	9 × 9	1 : 52	·019	47½	·58	·17	·0004				
40	12 × 12	1 : 40	·025	90	·62	·28	·0006	1	1·30	40	2,297,430
40	12 × 12	1 : 40	·025	70	·48			1	1·58	40	1,890,260
40	12 × 12	1 : 40	·025	110	·76	·27	·0005	1	1·92	40	1,555,550
40	14 × 14	1 : 34	·029	120	·61	·30	·0006				
40	15 × 15	1 : 32	·031	140	·62	·27	·0005	1	1·07	40	1,143,300
40	15 × 15	1 : 32	·031	170	·75	·12	·0002	1	·75	40	1,631,120

[1] This column was added by the Author.

TABLE K.

RESULTS of EXPERIMENTS to ascertain the Resistance to Depression and Rupture, under a gradually increased Thrusting Stress, of Nine Specimens of Wood. (*Professional Papers, R.E.*, 1876.)

Test No.	Description.	Dimensions.		Length.	Per square inch.						Stress in pounds.								Depressions, inch.									Ultimate stress.	
		Size.	Area.		1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000	4200	4400	4600	4800	5000	5200	5400	Total.	per sq. in.
J		inches.	sq. ins.	ins.																								lbs.	lbs.
1280	Kawrie pine	6·00 by 4·00	4·00	36	·021	·027	·031	·035	·040	·045	·050	·054	·058	·062	·066	·070	·074	·078	·082	·086	·090	·095	·100	·105	·111	·122	..	126,456	5269
1279	English oak	6·00 ,, 6·00	36·00	36	·022	·032	·040	·049	·058	·062	·070	·080	·088	·096	·104	·112	·128	·148	·194	..	..	..	..	..	..	..	..	142,080	3946
1278	Canadian red pine .	6·00 ,, 6·00	36·00	36	·022	·031	·038	·043	·050	·056	·060	·066	·072	·082	·095	·120	..	..	..	..	..	..	..	..	..	..	..	115,299	3203
1277	Riga fir .	5·95 ,, 5·90	35·10	36	·046	·060	·072	·086	·100	·120	·142	·164	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	87,728	[2]2499
1276	Riga fir .	5·05 ,, 4·00	20·20	24	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	47,790	[2]2365
1274	Spruce pole	6·75	35·78	12	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	150,880	4217
1275	Larch, green	6·18	30·00	36	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	78,410	2614
					300			400			500			600			700			800			900			1000			
1282	Spruce pole	6·05	28·50	[1]198	·080			·108			·135			·164			·193			·230			·272			..		29,785	1045
1281	Riga fir .	4·18 by 5·04	21·06	[1]112	·092			·130			·182			·245			·303			·397			·460			..		20,859	990

Tensile strength of spruce pole, J 1283 = 9073 lbs. per square inch.

Nos. 1274, 1282, and 1283 were the same pole.

Nos. 1281 and 1276 ,, baulk.

[2] Different specimens.

Both ends of the seven specimens were faced in the lathe.

Short columns of greenheart = 10,280 lbs. crushing resistance per square inch.

[1] Both ends of the two specimens were rounded thus.

DAVID KIRKALDY,

99 Southwark Street, London, S.E., 26th May 1875.

APPENDIX VII.

(*See page* 141.)

Ordinary Stock Sizes of Planks, Deals, and Battens, and the Scantlings into which they are most readily converted.

Inches.		Inches.	Inches.		Inches.
11×4	planks rift into	$5\frac{1}{2} \times 4$	7×4	battens rift into	$3\frac{1}{2} \times 4$
11×3	,, ,,	$5\frac{1}{2} \times 3$	7×3	,, ,,	$3\frac{1}{2} \times 3$
$11 \times 2\frac{1}{2}$	,, ,,	$5\frac{1}{2} \times 2\frac{1}{2}$	$7 \times 2\frac{1}{2}$	,, ,,	$3\frac{1}{2} \times 2\frac{1}{2}$
11×2	,, ,,	$5\frac{1}{2} \times 2$	$6\frac{1}{2} \times 2\frac{1}{2}$	,, ,,	$3\frac{1}{4} \times 2\frac{1}{2}$
9×4	deals rift into	$4\frac{1}{2} \times 4$	6×2	,, ,,	3×2
9×3	,, ,,	$4\frac{1}{2} \times 3$	5×2	,, ,,	$2\frac{1}{2} \times 2$
$9 \times 2\frac{1}{2}$	,, ,,	$4\frac{1}{2} \times 2\frac{1}{2}$	$4\frac{1}{2} \times 2$	,, ,,	$2\frac{1}{4} \times 2$
9×2	,, ,,	$4\frac{1}{2} \times 2$	4×2	,, ,,	2×2
8×4	,, ,,	4×4			
8×3	,, ,,	4×3			
8×2	,, ,,	4×2			

They can be obtained in lengths of from 6 or 8 feet to 18 or 20 feet, and even a few longer lengths if required.

APPENDIX VIII.

(*See page* 217.)

Standard Wire and Sheet Metal Gauge, as approved by Her Majesty's Order in Council, 1st March 1883, to be the Board of Trade Standards from 1st March 1884.

Descriptive Number B.W.G.	Equivalent in parts of an inch.	Metric equivalent in millimetres.	Descriptive Number B.W.G.	Equivalent in parts of an inch.	Metric equivalent in millimetres.
No.		mm.	No.		mm.
7/0	0·500	12·700	23	0·0240	0·6100
6/0	464	11·785	24	0220	0·5590
5/0	432	10·973	25	0200	0·5080
4/0	400	10·160	26	0180	0·4570
3/0	372	9·449	27	0·0164	0·4166
2/0	348	8·839	28	0148	0·3759
0	324	8·229	29	0136	0·3454
1	300	7·620	30	0124	0·3150
2	276	7·010	31	0116	0·2946
3	252	6·401	32	0108	0·2743
4	232	5·893	33	0100	0·2540
5	212	5·385	34	0·0092	0·2337
6	192	4·877	35	0084	0·2134
7	176	4·470	36	0076	0·1930
8	160	4·064	37	0068	0·1727
9	144	3·658	38	0060	0·1524
10	128	3·251	39	0052	0·1321
11	116	2·946	40	0048	0·1219
12	104	2·642	41	0044	0·1118
13	0·092	2·337	42	0040	0·1016
14	080	2·032	43	0036	0·0914
15	072	1·829	44	0032	0·0813
16	064	1·626	45	0028	0·0711
17	056	1·422	46	0024	0·0610
18	048	1·219	47	0020	0·0508
19	040	1·016	48	0016	0·0406
20	036	0·914	49	0012	0·0305
21	032	0·813	50	0·0010	0·0254
22	0·028	0·711			

INDEX.

THE END

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